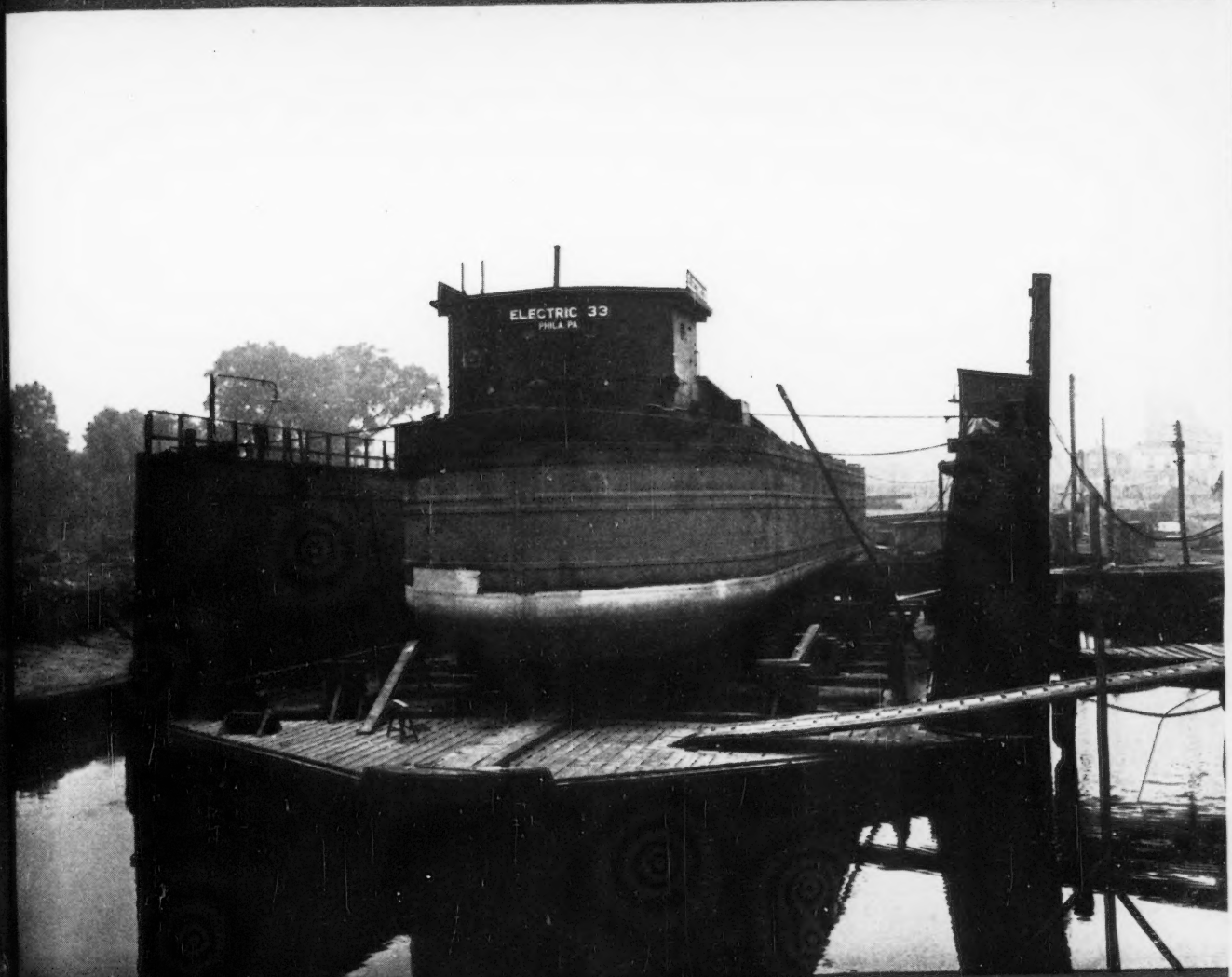
Corrosion

Official Publication
NATIONAL ASSOCIATION OF CORROSION ENGINEERS



Vol. 7 SEPTEMBER, 1951 No. 9

CORROSION CRIPPLES-MORE WAYS THAN ONE

Valuable products as well as vital equipment are threatened

Corrosion takes its toll in more ways than one—it eats away costly, hard-to-get equipment—wastes man-hours while plants are shut down for repairs—and causes loss of vitally-needed products through contamination.

Every industry suffers from corrosion in some form, yet much of this waste can be avoided by taking these steps:

1. Check manufacturing equipment, storage tanks, and other items exposed to corrosive fumes, acids, alkalies, or moisture.
2. Arrange to protect them with AMERCOAT — the corrosion resistant coatings, each built to conquer specific industrial corrosion problems.

Manufacturers in nearly every industry have found that it pays to protect — protect with AMERCOAT.

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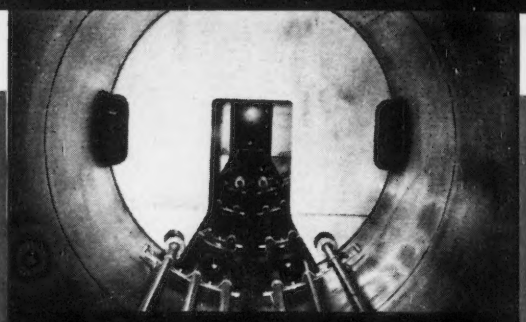
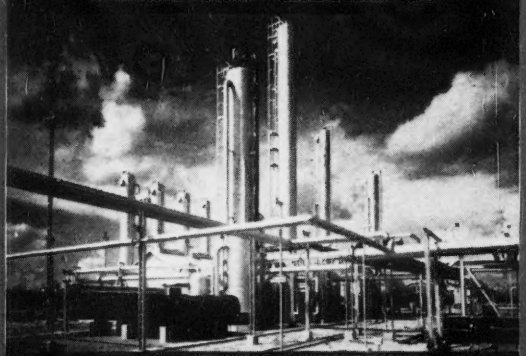
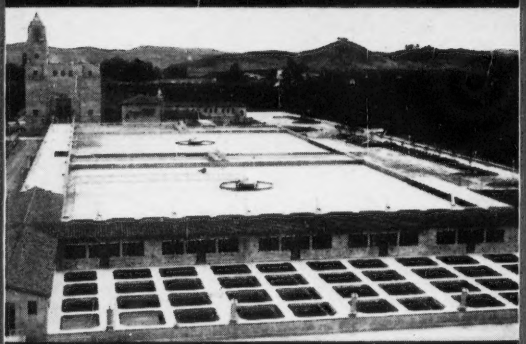


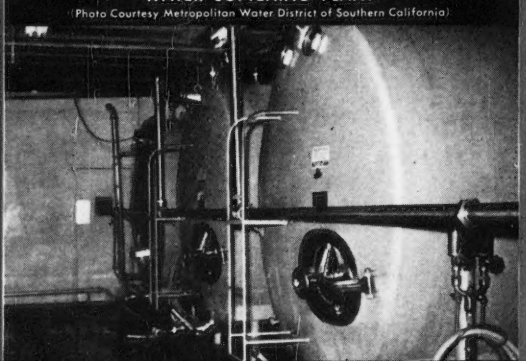
CHEMICAL PLANTS — Caustic Soda Tank



PETROLEUM REFINING — Columns and Piping



WATER SOFTENING PLANT
(Photo Courtesy Metropolitan Water District of Southern California)



FOOD PROCESSING — Milk Storage Tanks

TEXTILE MILLS — Dyeing and Finishing

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Bitumastic 70-B Enamel being machine-applied to a 20-inch gas transmission line.

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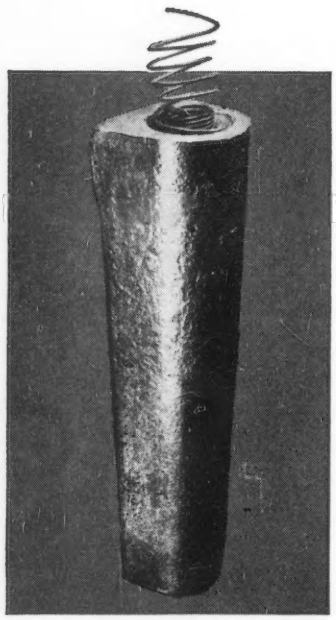

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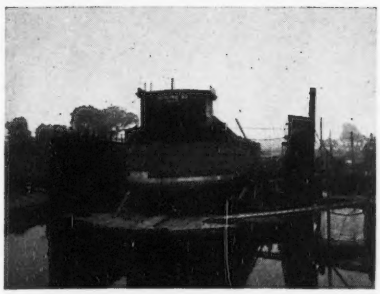

THIS MONTH'S COVER—This Delaware River coal barge operated by the Oliver Transportation Company is one of several in service since 1933 which have shown little or no loss of hull structural strength as a result of a coating system involving metallizing with .006 to .008-inch zinc, sealing with a thin synthetic and one or two coats of marine paint. Ordinary painting is inadequate to protect the hulls from corrosives in the river water. Maintenance repainting is simple because of lack of corrosion. Damage to the protective zinc by abrasion can be patched easily by the Metallizing Process.

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OCTOBER:

Filamentary Growths on Metal Surfaces—"Whiskers".
By K. G. Compton, A. Mendizza and S. M. Arnold.

Passivating Characteristics of the Stainless Steels
By W. G. Renshaw and J. A. Ferree

Economics of Rectifier Installations for Cathodic Protection of a Bare Pipe Line
By D. C. Glass

Prevention of Corrosion in Naval Aircraft. Part I of Two Parts.
By N. E. Promisel and G. S. Mustin

Topic of the Month—A New Electrolysis Switch for Underground Lead Sheath Cable Drainage Systems.
By V. B. Pike

NOVEMBER:

Effect of Packaging on Corrosion of Zinc Plated Equipment.
By B. G. Compton, S. M. Arnold and A. Mendizza

Area Affects in Crevice Corrosion.
By O. B. Ellis and F. L. LaQue

Prevention of Corrosion in Naval Aircraft. Part II of Two Parts
By N. E. Promisel and G. S. Mustin

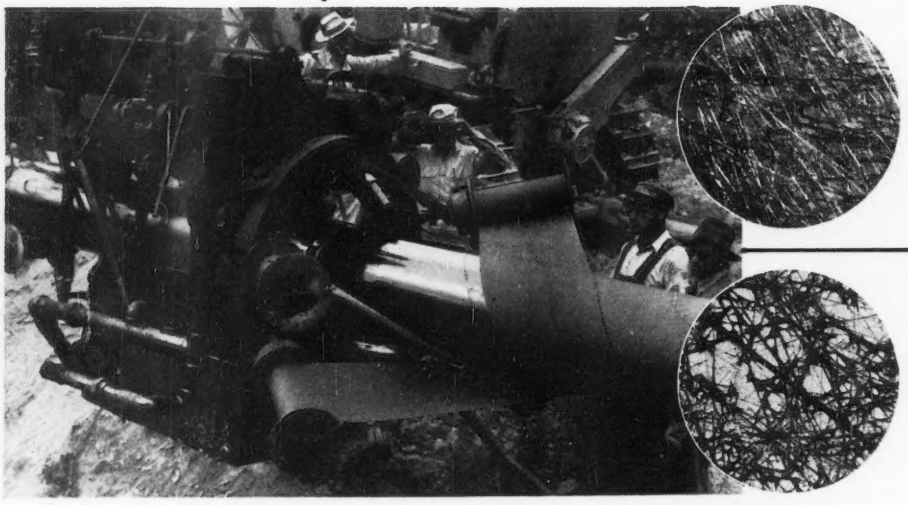
Corrosion Inhibition in Gas Condensate Wells by Intermittent Injection of Alkaline Solutions
By Charles C. Nathan

Some Aspects of Ship Bottom Corrosion
By Paul Ffield

See why CAREY GLASFLOSS

made from DRAWN fibers

REINFORCES COATING BEST



Carey Glasfloss—made of two layers of long, drawn fibers, uniform in size and cross section. Fibers in each layer are parallel, evenly spaced, and cross at an angle with fibers in the other layer.

Blown-type mat—fibers are short, non-uniform in size and cross section, unevenly spaced. Reinforcement cables are spaced at approximately ¼" intervals to strengthen mat sufficiently for application.

Compare the two types of glass pipeline wrap illustrated. One is *Carey Glasfloss,* made from evenly-spaced, uniformly drawn fibers. The other, a well-known brand made from blown fibers.

The long fibers in the *Glasfloss* mat are uniform in size and cross section . . . cross in 2 hi-strength layers at an angle with each other. In the blown-type mat, fibers are so short, non-uniform in size and cross section, and so haphazardly arranged that reinforcing cables are required!

For strengthening pipeline coating, the advantages of *Carey Glasfloss,* are obvious:

1. The Glasfloss mat made of two layers of long drawn, evenly spaced fibers gives the greatest reinforcement possible throughout the coating . . . makes it tough, resistant to shatter and cold flow.

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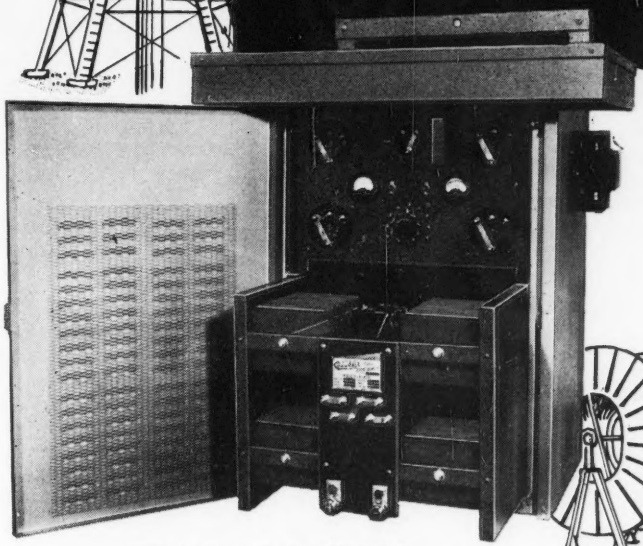

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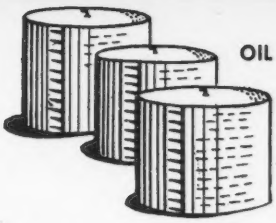

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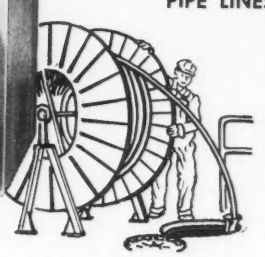

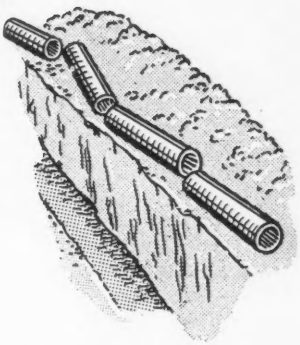

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RUST-OLEUM is the practical answer to a wide range of rust problems. For more than a quarter of a century RUST-OLEUM has been proved under severe conditions of weather, fumes, salt air, salt spray, and other rust producing conditions.

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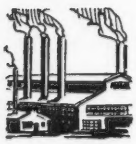

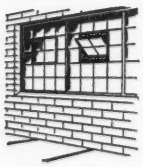

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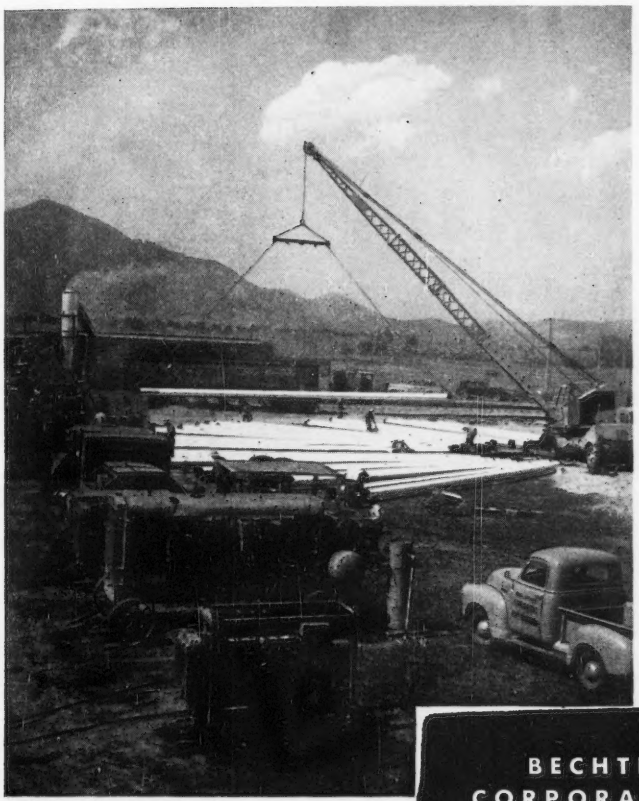

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Somastic Pipe Coating is a special mixture of asphalt-mix mastic compounded to rigid specifications and firmly bonded to the pipe as a thick seamless coating. Overlapping field joints of the same mixture make this protection continuous along the pipe line.

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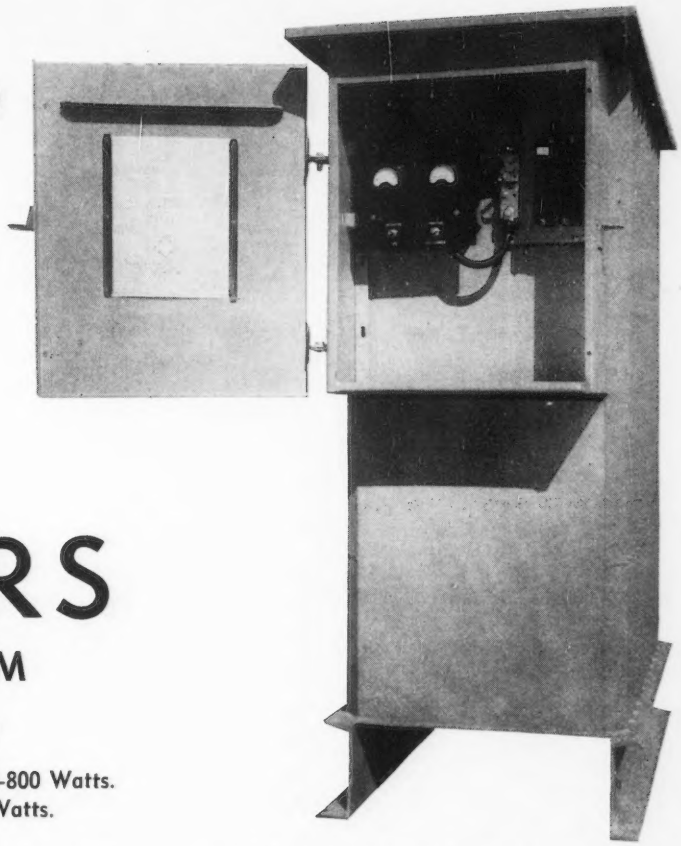

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OIL IMMERSED SELENIUM

Capacities to Fit Your Design

Two Straight-Sided Models—Up to 400 Watts and 400-800 Watts.
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Don't have expensive crews standing around idle. Brance-Krachy can ship your complete cathodic protection system, — anodes, cable, shunts, bonds, insulators, instruments—on one order, one delivery. *Have everything there when you're ready to go.*

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To help you lengthen equipment life and save critical materials . . . . . .

Some important facts about
GALVANIC CORROSION
and how you can control it

With strict conservation of basic defense materials again the order of the day, this brief discussion of bi-metallic corrosion may save you a few unnecessary headaches

When two dissimilar metals are coupled in a corrosive liquid – brine, for example – one metal is often attacked by corrosion at a faster rate than usual.

The second metal may remain free from attack. Or it may be corroded at a slower rate than usual.

This type of corrosion is known as "galvanic corrosion."

What to look for

Before blaming galvanic action for corrosion in your equipment, you should first determine whether these three conditions exist:

1. **Are the metals different?**
2. **Are they surrounded by an electrolyte?**
3. **Are they in electrical contact through a metallic path?**

A "yes" answer to all three questions should send you to the "Galvanic Series" chart reproduced at the right. Here the metals are listed in the reverse order of their "nobility" or resistance to galvanic corrosion.

Galvanic corrosion usually results in a higher rate of corrosion of the "less noble" metal, and protection of the "more noble" metal.

How to use the chart

Notice how the metals are grouped. Any metal in one group can safely be used with any other metal in its own group. When you start mixing metals from different groups, however, you may run into serious galvanic corrosion of the metal higher on the list. And the further apart the metals stand, the worse this corrosion may be.

Another thing to consider in using different metals, too, is the electrical contact between them. When the metals are separated or insulated in some way, galvanic corrosion is checked.

And a third factor to keep in mind is the relative areas of the two metals. If they are in contact with each other, make sure that the parts having the smaller area are more noble than those having the larger area.

Application

With these principles as a guide, you can tell which metals are apt to produce strong galvanic corrosion. And you can tell which are relatively safe to use in contact with each other. For example, Monel fastenings could be used on a steel tank holding a liquid without fear of galvanic corrosion.

Why? Because the relative areas of the two metals are such that the area of the less noble metal, steel, is much greater than that of Monel. Since the magnitude of the galvanic action depends to a large extent on this area ratio, corrosion in the steel will not be accelerated to any appreciable extent.

Two good suggestions

1. Write for our free booklet, *Corrosion—Processes, Factors, Testing.* It contains a thorough explanation of galvanic corrosion, with data on the characteristics of Monel, Nickel and Inconel.

2. If you have a metal problem, take it up with INCO's Corrosion Engineering Service. Available data from their files for a particular combination of metals will be furnished wherever possible. And Corrosion Engineering will be glad to help you apply general principles of galvanic corrosion control to your specific problems.

GALVANIC SERIES OF METALS AND ALLOYS

Corroded End
(anodic, or least noble)

▼

Magnesium
Magnesium alloys

▼

Zinc

▼

Aluminum 2S

▼

Cadmium

▼

Aluminum 17ST

▼

Steel or Iron
Cast Iron

▼

Chromium-iron (active)

▼

Ni-Resist

▼

18-8 Stainless (active)
18-8-3 Stainless (active)

▼

Lead-tin solders
Lead
Tin

▼

Nickel (active)
Inconel (active)

▼

Brasses
Copper
Bronzes
Copper-nickel alloys
Monel

▼

Silver solder

▼

Nickel (passive)
Inconel (passive)

▼

Chromium-iron (passive)
18-8 Stainless (passive)
18-8-3 Stainless passive)

▼

Silver

▼

Graphite
Gold
Platinum

▼

Protected End
(cathodic, or most noble)

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TRADE MARK

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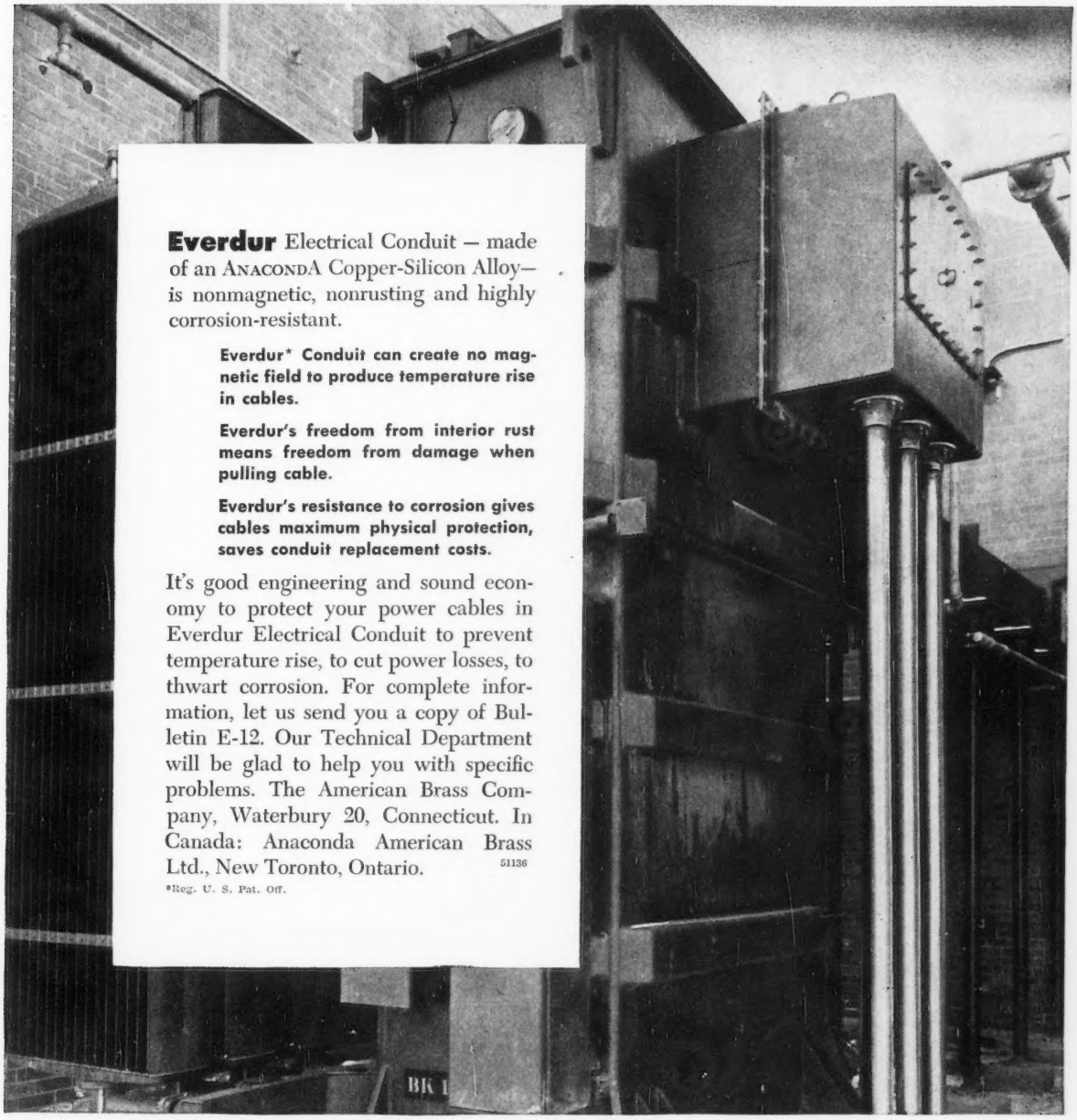
Everdur Electrical Conduit installation to junction box of a 7,500 kva transformer at Dunkirk, N. Y., Steam Station of Niagara Mohawk Power Corp. Each conduit contains 1-conductor cable carrying 300 amperes at 13,800 volts. Separate conduits provide complete phase isolation.



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Everdur* Conduit can create no magnetic field to produce temperature rise in cables.

Everdur's freedom from interior rust means freedom from damage when pulling cable.

Everdur's resistance to corrosion gives cables maximum physical protection, saves conduit replacement costs.

It's good engineering and sound economy to protect your power cables in Everdur Electrical Conduit to prevent temperature rise, to cut power losses, to thwart corrosion. For complete information, let us send you a copy of Bulletin E-12. Our Technical Department will be glad to help you with specific problems. The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario. 51136

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EVERDUR ELECTRICAL CONDUIT

ANACONDA®

THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 919 Milam Building, 803 Texas Avenue, Houston 2, Texas.

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NACE — A Virile Vehicle for An Organized Attack on Corrosion

By NORTON E. BERRY, President
National Association of Corrosion Engineers

ONE OF MARK TWAIN'S most famous quips was, "Everybody talks about the weather but nobody does anything about it." This humorous gem has lost some of its pungency today, when through the use of air conditioning, scientific weather forecasting and artificial rain making, something is being done.

But in Mark Twain's day "the weather" was largely a subject for polite and somewhat aimless conversation. It was only through subsequent organized scientific discussion that something came to be done about it.

With some reservations, this same comment might have been applied to the subject of "corrosion." It could hardly be claimed that it has enjoyed the same conversational popularity as the weather, but it is true that the destructive effects of corrosion were well recognized long before too much was done about it. And it is equally certain that much more can and will be done with resultant immeasurable benefits to mankind.

The one over-riding purpose of the National Association of Corrosion Engineers is to promote and accelerate the attainments of those benefits. It seeks to do this by providing a concentrated forum for verbal discussion and visual observation, a medium for written discussion and, through its Technical Practices Committees, the organized means for more direct attack on specific problems or groups of problems.

The direct benefits to individual and corporate members need little comment. The dollar value of one new thought, in terms of professional advancement or corporate profit, can hardly fail to reduce the investment to insignificance. But this does not constitute the major justification for investment in NACE. It is the constant and cumulative effect of "bread cast upon the waters" that will bring the larger return as benefits to all.

For the officers, directors, committee chairmen, committee members and technical contributors, the investment of time and effort is often great but the return is greater. In this respect NACE should find itself near the top of any list of "blue chip" investments. In an association with the obvious virility of NACE, where cooperation is taken as a matter of course and where selfish motives are so rare as to be indiscernible, the holding of any office or committee membership can scarcely fail to be a pleasurable experience.

Just a word about the office of President, which I count it a great privilege to hold. The duties are the usual with a sprinkling of the unusual; the hours are irregular and somewhat unpredictable; and the financial remuneration is negative but over-balanced by other compensations which are immeasurable.

I wish to take this means of expressing my gratitude to the membership for the opportunity of sharing in this memorable experience. I shall try to deserve the compensation.

Dicyclohexylammonium Nitrite, A Volatile Inhibitor for Corrosion Preventive Packaging★

By A. WACHTER*, T. SKEI* and N. STILLMAN**

Abstract

Dicyclohexylammonium nitrite is a powerful inhibitor for corrosion of steel by fresh water. Since this nitrite salt is slightly volatile, it has commercial application in a new method for preventing corrosion of packaged steel articles by the moisture that enters or is present within a package. It functions by vaporization and transport of its vapor to the metal surface where it condenses or dissolves in condensing moisture. The duration of protection is dependent upon the quantity of inhibitor present and the rate of loss as vapor and by decomposition. The compound has properties of chemical stability, compatibility, volatility, vapor transport, diffusion, solubility, and corrosion inhibition, that are important to its functions as an inhibitor in packages. The absence of undesirable effects with nonmetallic materials, nonferrous metals, bimetallic couples and in handling by people are also of practical importance.

A large number and variety of tests in the laboratory and in outdoor exposure racks have given information on the performance of the inhibitor under many different conditions. A dynamic corrosion test has been developed that is useful for rapid evaluation of volatile corrosion inhibitors for packaging applications.

The inhibitor is most conveniently and effectively employed in the form of a coating on wrapping papers or on paperboard containers. In order to obtain good results it must be used properly. It is not a panacea.

IT IS WELL KNOWN that sodium nitrite is a highly effective inhibitor for the corrosion of steel by oxygen-containing water. In pure water at atmospheric temperatures even minute concentrations of nitrite can completely prevent corrosion.[1] Since this inhibiting action is ascribed to the nitrite ion, any salt liberating nitrite ion in neutral or alkaline solution would be expected to inhibit corrosion in the same manner. There are a great many nitrogen-containing organic compounds that react as bases in aqueous solution, as for example the various substituted amines, whose salts of nitrous acid likewise have been shown to be excellent corrosion inhibitors for ferrous alloys.[2] An outstanding member of this group of nitrite salts, mainly owing to its unusually good chemical stability, is dicyclohexylammonium nitrite.[3]

In comparison with the alkali metal nitrites this solid amine nitrite differs in being slightly volatile at atmospheric temperature. This property gives the compound special industrial importance because it makes possible the prevention of atmospheric corrosion of steel articles in packages or containers without the necessity for coating the steel with the inhibitor.[4] In such applications the vapors of Dichan (dicyclohexylammonium nitrite) are transported by convection and diffusion to all surfaces of the steel article. There the Dichan vapor can condense to give a thin layer of Dichan crystals, or dissolve in any condensed water film that may be present. By such means the corrosion inhibitor is brought to those locations on the metal surface at which corrosion would occur if the inhibitor were absent.

Since this amine nitrite is moderately soluble in water its protection of steel cannot be ascribed to formation of a hydrophobic adsorbed film; neither can it be ascribed to development of alkaline pH because an aqueous solution of the compound has a pH close to 7; nor can its action be ascribed to consumption of oxygen because the pure compound does not react detectably with oxygen from the air; nor can its action be attributed to moisture absorption by the salt because the compound is relatively non-hygroscopic. In view of these considerations, as well as the fact that the vapors of Dichan condense to give Dichan crystals, it must be concluded that the compound protects through the vapor phase by contributing its nitrite ion to condensed or adsorbed moisture on a metal surface, and that its volatility is merely a means of transport for the inhibitor.

For a volatile inhibitor of corrosion to be commercially applicable for protective packaging it must meet a special set of requirements. In essence, it must be easy and economic to apply, strikingly effective in preventing corrosion in a wide range of atmospheric conditions, it should have reasonable durability and be free from objectionable properties. The properties and behavior of dicyclohexylammonium nitrite with respect to its utility in protective packaging is the subject matter of this paper.

For commercial use in corrosion preventive packaging the inhibitor is most conveniently applied by coating paper or cardboard with the chemical. Such products designated VPI† now are available commercially. Many of the experiments reported here were made with paper containing Dichan uniformly coated over one surface.

★ A paper presented at the Seventh Annual Conference and Exhibition, National Association of Corrosion Engineers, New York, N. Y., March 13-16, 1951.

* Shell Development Company, Emeryville, California.

** Western Foil Converters, Inc., Berkeley, California.

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General Properties

Dicyclohexylammonium nitrite is a white crystalline solid, melting at about 310 degrees F with decomposition. It is practically odorless. The pH of its aqueous solutions is about 7.2.

The vapor pressure of a purified sample of Dichan was determined at several temperatures by the dynamic flow method. This method involves passing dry nitrogen at various flow rates over the powdered crystals at constant temperature, collecting the sublimed Dichan in a cold trap, and extrapolating the amount vaporized per unit volume of gas back to zero flow rate. Vapor pressures thus obtained are summarized in Table I. It is seen that this compound has about one-tenth the vapor pressure of mercury at room temperature. It can be calculated also that 1 gram of Dichan would saturate about 20,000 cu. ft. of air at room temperature.

As shown by the solubility data in Table II, Dichan is moderately soluble in water, is very soluble in methyl alcohol, only slightly soluble in low molecular weight polar solvents and practically insoluble in hydrocarbons. Considerably increased solubility is obtained by certain mixtures of alcohols with water, a few examples of which are given in Table II.

An approximate indication of the hardness of Dichan was obtained by rubbing crystals over scratch-free surfaces of different pure metals followed by inspection of the surfaces with moderate magnification. It was found that Dichan would scratch cadmium and tin but did not scratch aluminum (2S ½H), lead or copper. A Moh hardness of about 1 is indicated by these results.

TABLE I—Vapor Pressure of Dichan

°F	mm. Hg x 10^3
30	0.007
50	0.03
70	0.1
90	0.4
110	1.4
130	3.8
150	12

TABLE II—Solubility Data

Solubility of Dichan in Water

°F.	g. Dichan/100 g. Solution
32	3.0
77	3.9
113	5.2
149	6.9

Solubility of Dichan in Various Solvents (ca 75° F.)

Solvent	g. Dichan/100 g. Solution
Methyl alcohol	23.6
Ethyl alcohol	9.2
Isopropyl alcohol	2.2
Hexylene glycol	1.4
Acetone	0.2
Methyl ethyl ketone	0.08
Benzene	0.065
Carbon tetrachloride	0.006
Heptane	0.0002

Approximate Maximum Solubility in Mixed Solvents

70%w Ethyl alcohol, 30%w water	16.7
65%w Isopropyl alcohol, 35%w water	12.8
60%v. Methyl alcohol, 30%v benzene, 10%v water	28.9

In view of the wide-spread commercial applicability of Dichan, information regarding possible toxic hazards is important. Toxicity studies[5] with small animals have shown that Dichan is similar in its action and would have about the same degree of hazard as sodium nitrite. The intragastric LD_{50} (lethal dose for 50 percent of animals tested) is 205 mg per kg animal weight in mice, whereas sodium nitrite has an LD_{50} of 220 mg. No cumulative toxic effects could be detected nor were local irritant effects on skin observed. These results and commercial experience thus far indicate that undue hazards are not introduced under normal handling and use conditions. Owing to its very low vapor pressure it would not be expected to exert a detectable effect even if air saturated with Dichan were inhaled continuously.

Throughout the research on Dichan its concentrations and quantities were determined by analysis for nitrite content. The analytical procedure used for quantitative determination of nitrite was based on the colorimetric method described by Shinn,[6] involving development of a red color from reaction of nitrite in acidified solution with p-aminobenzenesulfonylamide and N-(1-naphthyl)-ethylenediamine.

Tests of Corrosion Inhibiting Effectiveness

A great many corrosion tests have been made, mostly with wrapping paper containing Dichan, in the laboratory and in outdoor exposure. A variety of different types of test were made in the laboratory because no single test is known which embodies all the conditions and sequences of terrestial weather. Also, consistent performance of an inhibitor in a variety of test procedures inspires greater confidence in the validity of conclusions therefrom.

Minimum Concentration for Rust Prevention

Corrosion tests were made under stagnant conditions to determine the minimum concentrations of Dichan in water for rust prevention on steel totally immersed in the water, on steel partially immersed, and on steel in the vapor above the water. Figure 1 is a photograph of the test strips after 500 hours at 100 degrees F. Complete protection was obtained at all strip locations with a concentration of 4 percent Dichan. Totally immersed steel was protected perfectly at concentrations down to 0.1 percent and showed only slight signs of corrosion at 0.01 percent. Increasing tendency to rust was observed in the vapor space as the concentration of Dichan in the water was decreased to 2 percent and lower. In no case with Dichan present was localized corrosion observed at the water-air interface.

Humidity-Cabinet Vapor-Phase Corrosion Tests

Tests were made in individual containers consisting of 1 by 6 inch glass test tubes. To the outside bottom of each tube a glass hook was sealed to permit suspension in an inverted position. Another glass hook was sealed to the bottom on the inside for suspension of a steel test strip. A piece of Dichan paper (one g Dichan per sq. ft.) large enough to cover the

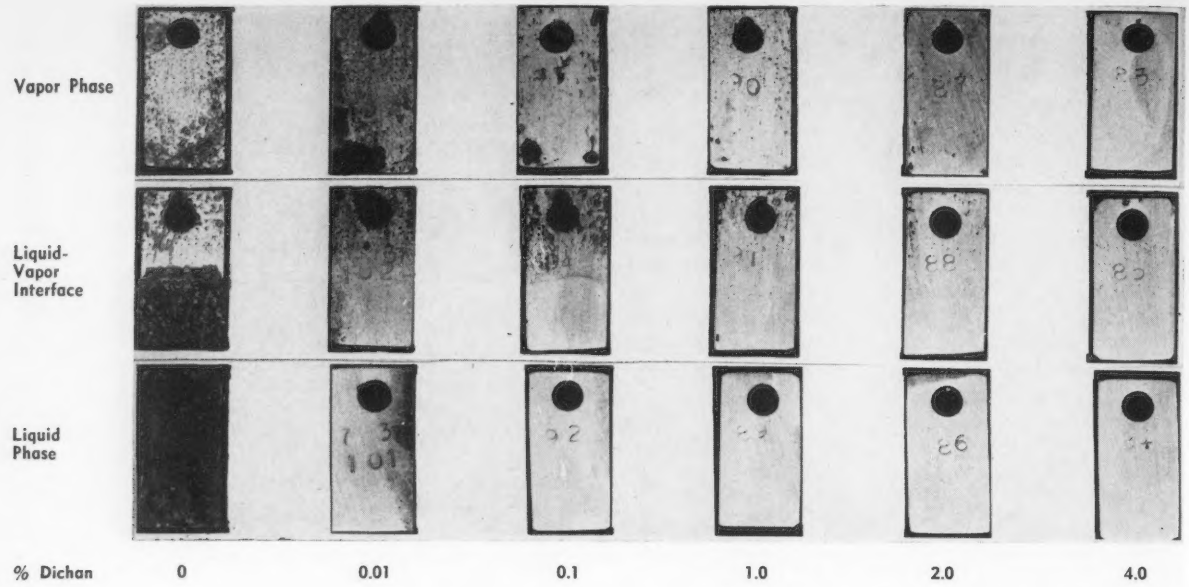


Figure 1—Minimum concentration for rust prevention.

inside surface of the tube was placed in the test tube and a polished strip of SAE 1020 steel, ¾ by 3 inches, with a hole at one end was suspended inside the tube. The tubes were then suspended in a humidity cabinet at 100 degrees F and *ca* 100 percent humidity for 400 hours. A large number of such tests showed complete protection against rusting, whereas controls with uninhibited paper rusted considerably. Typical results are illustrated in Figure 2.

A special series of these tests was made for a total period of 21 days each to determine the effect of Dichan content of paper on performance. Results summarized in Table III show that steel is protected under these conditions by 0.3 g per sq. ft. Dichan loading for at least 21 days, but that 0.1 g per sq. ft. prevents corrosion only for a few days.

Another series of humidity cabinet tests with different loadings of Dichan on paper was made in which steel strips were wrapped in the inhibitor paper and over-wrapped with a waxed paper. Results given in Figure 3 show that conditions were more severe than in the previous series and indicate that duration of protection is directly proportional to the amount of Dichan initially present.

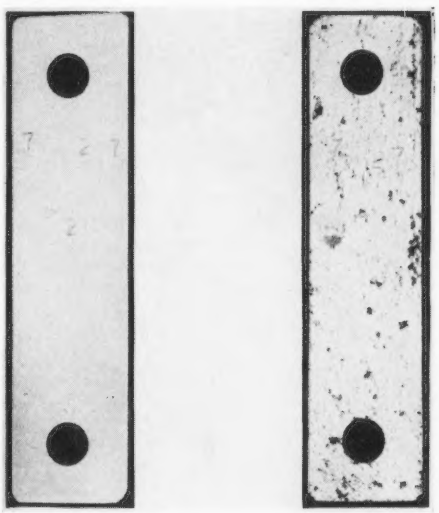


Figure 2—Humidity cabinet vapor phase corrosion test.

TABLE III—Humidity Cabinet Tests with Various Dichan Content Papers

Polished mild steel strip (¾ by 3 inches) suspended from a glass hook in inverted 1-inch test tube lined with a single thickness of Dichan paper (2.75 x 5 inches). Test tubes closed with a cork having a ⅜-inch diameter hole and suspended stoppered end down in humidity cabinet at 100° F and ca 100 percent humidity. Paper punch samples for Dichan analysis were taken from the bottom of the paper at each inspection.

	0 Days	4 Days		8 Days		14 Days		21 Days	
	Dichan g./sq. ft.	Dichan g./sq. ft.	Percent Rust	Dichan g./sq. ft.	Percent Rust	Dichan g./sq. ft.	Percent Rust	Dichan g./sq. ft.	Percent Rust
Control, no Dichan	....	....	30	....	30	....	45	....	45
Dichan impreg. paper	0.11	0.03	tr	0.01	tr	0.00	6	0.00	30
Dichan impreg. paper	0.33	0.20	0	0.16	0	0.10	0	0.09	0
Dichan impreg. paper	0.53	0.49	0	0.45	0	0.45	0	0.39	0
Dichan coated paper	0.10	0.02	4	0.01	20	0.00	25	0.00	70
Dichan coated paper	0.31	0.17	0	0.07	0	0.04	0	0.03	0
Dichan coared paper	0.47	0.38	0	0.25	0	0.15	0	0.09	0

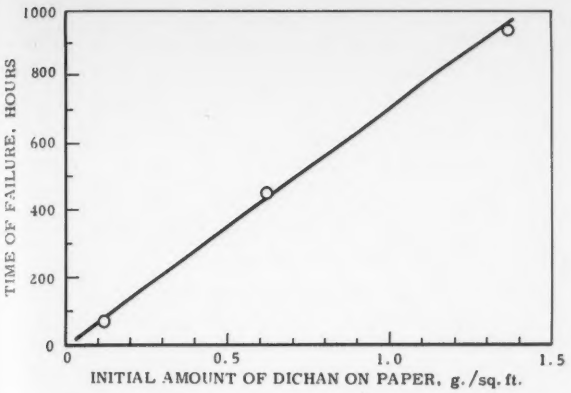


Figure 3—Duration of protection in humidity cabinet. Polished steel strips (¾ by 3 in.) were single-wrapped in kraft paper impregnated with various amounts of Dichan. The wrapped specimens were placed in Grade C, Type III Ordnance paper envelopes, the edges of which were stapled and sealed with wax. Packages were suspended in a cabinet at 100° F and ca 100 percent humidity, and inspected at intervals for rust. General appearance of rust over 25 to 50 percent of the surface constituted failure. (Dichan content of papers at time of failure varied from 0.001 to 0.005 g/sq. ft.)

Prolonged Vapor Phase Corrosion Test at 150 Degrees F

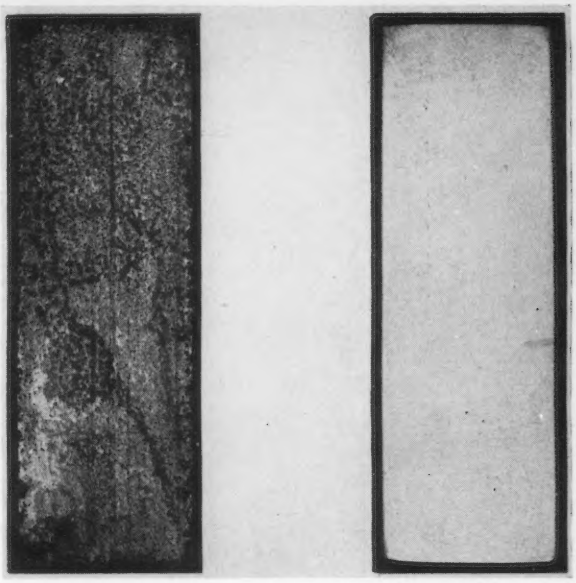
A vapor phase corrosion test of prolonged duration at 150 degrees F was made with polished steel strips suspended separately in tall-form quart bottles, containing a small quantity of Dichan crystals and of water. The bottle screw caps were drilled to provide a different diameter hole in each in order to allow escape of Dichan vapors. The bottom edge of the steel strip was about four inches from the bottom of the bottle over which was spread 0.5 g Dichan crystals. A very small glass beaker containing about five ml water was also placed in each bottle. The water was replenished as necessary. Vent holes in the three bottles containing Dichan were ⅛-inch, ¼-inch and ½-inch in diameter. The hole in the control test bottle without Dichan was ¼-inch in diameter.

After six months' exposure at 150 degrees F the steel strips above the Dichan crystals were protected perfectly while the control rusted considerably.

Temperature Cycle Corrosion Test at High Humidity

Corrosion tests were made with small packages employing Dichan coated paper in a laboratory climatizer in which humidified air (95 to 100 percent humidity) was passed separately over each package at 20 ft. per minute once through. The air temperature was cycled under automatic control, 4 hours at 60 degrees F, 16 hours at 93 degrees F, and 4 hours heating and cooling between these temperatures. These tests were made for a total of 28 days with clean polished heavy bar steel (1 by 1 by 3 in.) specimens wrapped in Dichan coated paper in cardboard boxes overwrapped with kraft-asphalt-kraft paper. Controls, identical in every respect except that Dichan was omitted, were tested at the same time. Typical results illustrated in Figure 4, show the excellent protection provided by the Dichan despite the strongly corrosive conditions prevailing in this test.

Tests with much more extreme temperature cycles (150 degrees F to —10 degrees F), but for brief periods, were made with inhibitor paper containing different loadings of Dichan. Results summarized in Table IV show that a minimum of about 0.5 g Dichan was required for complete protection of steel under these conditions of severe shock heating and cooling.



Kraft Paper Dichan Paper

Figure 4—Temperature cycle corrosion test at high humidity.

Prevention of Further Corrosion on Rusted Steel

The performance of Dichan paper in preventing further rusting of rusted steel is illustrated by results shown in Figure 5. Three separate drops of water were placed on each of four strips of polished mild steel which were then allowed to stand at room temperature until dry. The top half of Figure 5 shows the appearance of the strips at this point, the area covered by each drop having rusted.

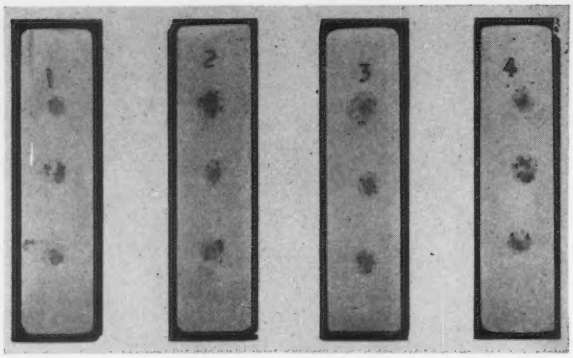
Two of these strips then were wrapped in a single thickness of paper containing 1.0 g Dichan per sq. ft. and two strips were wrapped in untreated paper. After 500 hours' storage at 100 degrees F in a closed container with sufficient water to reach 100 percent humidity, the strips were removed and photographed again. The effectiveness of Dichan paper in preventing further rusting and rust spreading is clearly seen by comparing the bottom half of Figure 5 with the upper half.

Weight-loss corrosion tests with prerusted steel immersed in solutions of Dichan or wrapped in

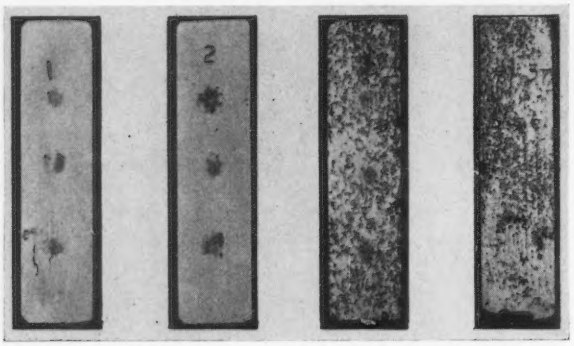
TABLE IV—Shock Temperature Cycle Corrosion Tests

Polished steel strip, ¾ by 3-inch, wrapped in single layer of Dichan impregnated paper and suspended in stoppered flask containing 1 ml. water. Flasks subjected to 24 cycles of 150° F. for 45 minutes and 15 minutes in a dry ice chamber which cooled the air inside each flask to —10° F. Duplicate tests made at each Dichan content.

Dichan Content of Paper Wrap, g./sq. ft.	Appearance of Steel Strips
0	Rusted all over
0.09	Rusted all over
0.23	1) Rusted considerably 2) Almost no rust
0.46	No rust
0.94	No rust
1.72	No rust



Initial Appearance



Wrapped in Dichan Paper Wrapped in Untreated Paper

Appearance after 500 hours at 100 degrees F and 100 percent humidity

Figure 5—Prevention of further corrosion.

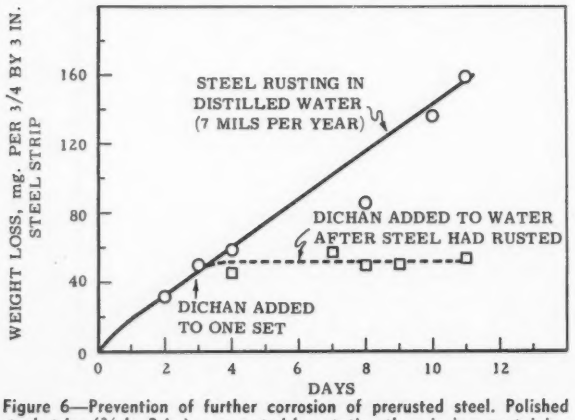


Figure 6—Prevention of further corrosion of prerusted steel. Polished steel strips (¾ by 3 in.) were rusted by rotating them in jars containing 100 ml of distilled water at 150° F (air atmosphere). Some strips were removed after 2 and 3 days to establish the corrosion rate in water. After 3 days the strips were heavily rusted and solid Dichan was added to the water in some jars to a concentration of 2 percent. The tests were continued and strips were removed from water and the Dichan solutions at intervals to determine weight loss.

Dichan paper and exposed to hot humid air, support the qualitative observation that the inhibitor is capable of preventing further rusting of previously rusted steel. These experiments and results are described in Figures 6 and 7.

Low-Temperature Corrosion Tests

Several experiments were made to determine the effectiveness of Dichan at low temperatures. Polished

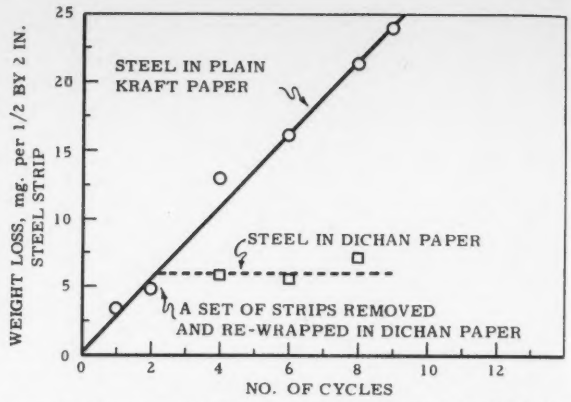
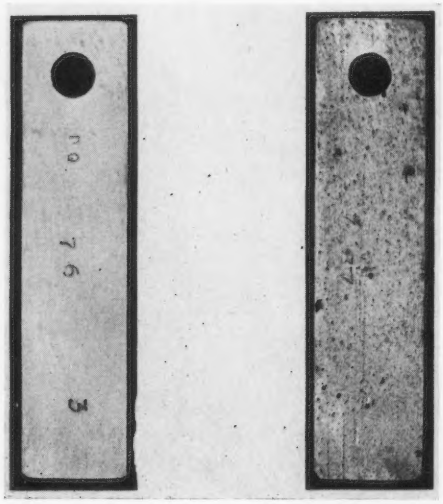


Figure 7—Prevention of further corrosion of prerusted steel. Polished steel strips (½ by 2 in.) wrapped in a single fold of 60-lb. kraft paper were suspended over 1 ml water in a stoppered 500 ml flask. The flasks were heated to 150° F for 30 minutes and cooled to 0° F for 15 minutes. This temperature treatment constituted 1 cycle. After the second cycle the strips were covered with rust. Several of these strips then were removed and wrapped in 60-lb. kraft paper containing 1.8 g Dichan per sq. ft., and cycle treatment continued with both groups. Triplicate strips were removed at intervals and their weight loss determined.



With Dichan Paper With Untreated Paper

Figure 8—Low temperature cycle test.

steel strips (¾ by 3 in.) were suspended in 250 ml glass stoppered bottles lined with 1 g per sq. ft. Dichan coated paper and containing 0.5 ml water. Each steel strip was about one inch from the sides and one inch from the bottom of the bottle. Control tests were made with uninhibited kraft paper. Bottles were stored for 14 days at —30 degrees F, then four hours at room temperature (*ca* 70 degrees F). This cycle was repeated four times. Excellent protection was obtained with Dichan in comparison to controls (Figure 8).

Similar experiments for longer periods were made in which the bottles were stored in a refrigerator at 40 degrees F without cycling. Controls with plain kraft paper were slow in developing rust, only little rust appearing in one month, but marked rusting developed in two months. After one year of storage the

controls showed considerable rust over 30 to 40 percent of the steel surface, whereas those with Dichan showed only a trace or a few slight specks of rust.

Package Corrosion Tests Outdoors

A great many tests in outdoor exposure have been made with steel in different shapes in a large variety of packages employing Dichan paper. These were made under partial shelter, which merely protected the packages from direct rain, and also were made completely exposed to the weather. The test site was on the roof of a two-story building on the banks of the Oakland Estuary on San Francisco Bay in California. Average summer temperatures varied daily from about 53 degrees F to 71 degrees F, average winter temperatures varied daily from about 41 degrees F to 58 degrees F, and humidities from about 65 percent to 86 percent. The annual rainfall averages about 17 inches. Wind blows almost continuously and its velocity is mostly greater than nine miles per hour. A view of the test site and racks is given in Figure 9.

Some of the results obtained in these outdoor tests are summarized in Tables V and VI, and illustrated in Figure 10. It is noteworthy that excellent protection was given by the Dichan in rather simple packages over exposure periods of four and five years, and that protection was better than obtained with good rust preventive oils.

Influence of Oil on Inhibitor Performance

In many instances the presence of oil on a packaged machine or part is unavoidable or even desirable. Since Dichan is virtually insoluble in hydrocarbon fluids it would be important to know if Dichan paper which had absorbed oil from the packaged article would thereby suffer impaired effectiveness. It is reasonable, and has been demonstrated in package exposure tests, that an oil film on steel (either lubricating oil or temporary rust preventive oils) does not diminish the degree or duration of protection by Dichan. No decrease in efficiency was noted in several long duration tests in outdoor storage of packages containing heavily oiled parts wrapped in Dichan paper. However, the Dichan paper in these tests did not become completely covered with oil.

Experiments to determine the effects of soaking Dichan paper in oil on volatility and corrosion prevention are summarized in Tables VII and VIII. Although marked reduction of vaporization of Dichan resulted from soaking the inhibitor paper in oil, no decrease in protective action was observed in moderately severe corrosion tests.

Figure 9—Outdoor test site. Industrial-marine location on roof of two-story building at Oakland estuary on San Francisco Bay.

TABLE V—Package Corrosion Test Outdoors

Cleaned machined SAE 1020 steel part wrapped in Dichan paper (or otherwise treated as noted) and placed in waxed cardboard box, then stored outdoors under shelter for 4 years.

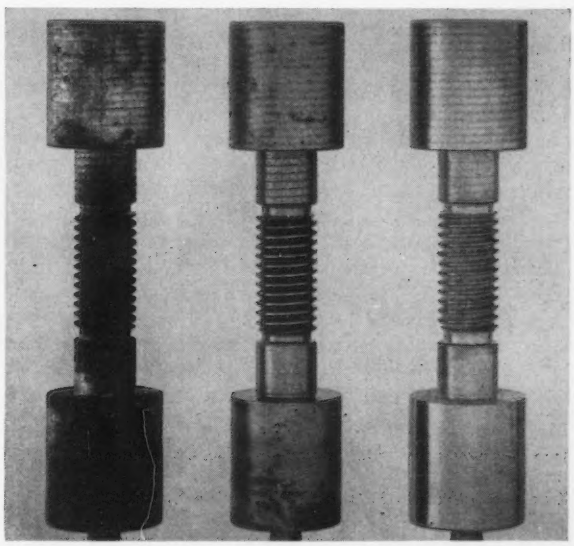
Inner Wrap	Percent Steel Surface Rusted
1 g./sq. ft. Dichan paper	0
2 g./sq. ft. Dichan paper	Trace
Kraft paper	50
Protective oil and grease-proof paper	1

TABLE VI—Package Exposure Tests Unsheltered Outdoors

Machined bars of SAE 1020 steel (1-inch diameter by 5-inch), solvent cleaned, stored with and without protective oil treatment, in packages composed of inner wrap of plain kraft or of kraft impregnated with 2 to 3 g Dichan per sq. ft. and outer wrap of water-proof barrier laminates. Package edges stapled and sealed with wax. Packages exposed outdoors without shelter in industrial-marine atmosphere in Oakland, California.

Treatment of Steel Bar	Composition of Package		Percent Surface Rusted		Dichan Remaining at 5 Yr., g./sq. ft
	Inner Wrap	Outer Wrap	3 Yr.	5 Yr.	
None	Kraft	K-A-K[a]	55	85	....
None	Dichan paper	K-A-K[a]	0	0	0.7
Oil X[b]	Kraft	K-A-K[a]	5	10	....
Oil X[b]	Dichan paper	K-A-K[a]	trace	trace	0.07
Oil Y[b]	Kraft	K-A-K[a]	6	14	....
Oil Y[b]	Dichan paper	K-A-K[a]	2	2	0.23
Oil X	Kraft	Al foil-wax paper	3	60	....
Oil X	Dichan paper	Al foil-wax paper	0	0	1.1
Oil Y	Kraft	Al foil-wax paper	15	85	....
Oil Y	Dichan paper	Al foil-wax paper	trace	trace	0.6

[a] 60 lb. kraft—60 lb. asphalt—60 lb. kraft laminated paper.
[b] Commercial rust-preventive oils.



With Untreated Kraft Paper | With Protective Oil | With Dichan Paper

Figure 10—Five-year unsheltered outdoor package test.

TABLE VII—Vaporization of Dichan from Oil-Soaked Paper

Sheets of 1 gram per sq. ft. Dichan coated paper suspended in an air stream at constant velocity of 100 ft. per minute flowing over both sides of each sheet, at room temperature (ca 70° F.) Amounts of Dichan on paper determined as function of time by analysis of portions of each sheet for nitrite. One group of sheets pretreated by dipping in SAE 30 motor oil, another group by dipping in 10 percent solution of same oil in volatile aromatic solvent. Oil-treated papers allowed to drain in air for 16 to 24 hours prior to testing, during which solvent evaporated.

	Cumulative Percent Dichan Vaporized		
DAYS	Unoiled Dichan Paper	10 Percent Oil in Solvent Pretreatment	Undiluted Oil Pretreatment
7	50	20	6
14	78	32	11
21	90	42	14
28	97	45	17

TABLE VIII—Effectiveness of Oil-Soaked Dichan Paper

Polished strip of steel laid on disc of Dichan coated paper (1 gram per sq. ft.) supported over 10 ml of water in bottom of 500 ml capped jar. Stored at room temperature for 3 months. Tests made with several discs oil-soaked by immersion for 5 minutes in SAE 30 motor oil, or in 10 percent or 50 percent solutions of the oil in volatile aromatic solvent, followed by hanging the discs in air for 16 to 24 hours prior to testing. Similar treatment of plain kraft paper discs.

Paper Tested	Oil Pretreat of Paper	Percent of Steel Surface Rusted
Dichan paper	None	Trace
Dichan paper	10 percent oil in solvent	Trace
Dichan paper	50 percent oil in solvent	0
Dichan paper	Undiluted oil	0
Kraft paper	None	45
Kraft paper	Undiluted oil	70

Dynamic Performance Test for Volatile Corrosion Inhibitors

Considerable effort was applied to development of a rapid laboratory test that would give a more reliable indication of the efficacy of volatile corrosion inhibitors for protective packing than is offered by humidity cabinet tests or static tests in closed jars containing water. The objectives were to control the main factors influencing atmospheric corrosion and to obtain a severe test of the ability of a volatile inhibitor to provide protection. Although the test finally developed correlates reasonably well with results from package tests, it suffers from many of the limitations inherent in accelerated tests and may not be used as the sole criterion of the usefulness of an inhibitor for all preservative packaging applications. The test is most useful as a screening test for volatile inhibitors that may be commercially applicable to packaging steel articles, as a means of comparing different inhibitors under one arbitrary but reproducible set of conditions, and as an aid for quality control in manufacturing an inhibiting wrapping paper.

The dynamic performance test is made by passing clean air at 150 degrees F at the rate of 120 cc per minute for the test period of 44 hours through the apparatus illustrated schematically in Figure 11. The air is humidified by bubbling through a 1 percent solution of sodium chloride in distilled water, then passes through two empty tubes serving as spray traps, then through the third tube which is lined with the inhibitor paper (4 by 4.75-inch sheet) and then through a fourth tube also lined with inhibitor paper and containing the test specimens of polished steel. The linear velocity of air through each tube is about six inches per minute at the flow rate employed.

Test specimens are segments of SAE 1045 cold-finished steel, 5/8-inch diameter round bar mounted in 1-inch diameter blocks of black Bakelite in the manner employed for metallographic examination. One cross-section surface of the steel rod then is ground, polished and solvent cleaned prior to insertion of the block into the test apparatus. Thus only one surface requires polishing, surface contamination in handling is easily avoided, and only one surface is inspected after the test exposure. Specimens also can be re-used in many tests by regrinding and polishing. Special care must be taken to obtain a good bond between the Bakelite and steel and thus avoid a contamination-catching crevice at the junction.

It is interesting that several amines, including dicyclohexylamine and C_{12}-C_{18} aliphatic amines, which passed some static corrosion tests perfectly failed badly in the dynamic test and failed in package tests of one month in cyclic atmospheric conditions.

In making a performance test one specimen is placed in contact with a disc of inhibitor paper in order to determine if any contaminant is present in the paper that will cause corrosion by contact even if protection through the vapor phase is realized.

Effects on Nonferrous Metals

Since Dichan is a nitrite salt its effects on nonferrous metals completely immersed in its aqueous solutions would be expected to be similar to effects of sodium nitrite solutions.[1] Corrosion experiments in which weight loss measurements were made are described in Table IX for several nonferrous metals submerged in water and in water containing Dichan. Under these conditions of strong agitation several metals showed somewhat greater weight loss in the Dichan solution, but only to a significant degree with magnesium, zinc and cadmium.

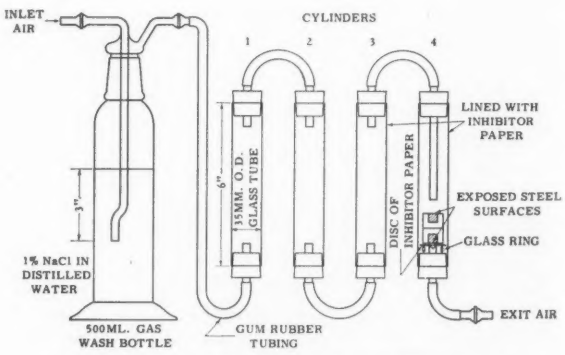


Figure 11—Apparatus for dynamic performance test.

TABLE IX—Effect of Dichan on Nonferrous Metals

Polished strips (5.50 by 0.375 inch) placed in stoppered 120 ml bottles containing 50 ml distilled water saturated with Dichan (ca 4 percent solution). Bottle rotated end-over-end at 60 rpm. at 86° F. for 14 days. The air in the bottles was changed several times. Control experiments were identical except that Dichan was omitted.

	CORROSION RATE, Mils/Yr.	
	Dichan Solution	Dist. Water
Aluminum 2S	0.2	0.3
70-30 Brass	0.2	0.06
Copper	0.4	0.4
Cadmium plate (on iron)	4.0	0.4
Zinc (galvanized iron)	10	2.0
Tin plate (on iron)	0.4	0.2
Lead	2.0	1.8
Magnesium	72	..

TABLE X—Galvanic Couples in Dichan Solution

Polished strips (¾ by 3 inch) of mild steel and nonferrous metal coupled together about 1/16 inch apart. Each couple immersed in 30 ml of 3.5 percent w Dichan solution in stoppered test tube. Stored at room temperature (about 70° F.) for 3 months. Solutions aerated once a week. A strip of each alloy, uncoupled, was tested alone under the same conditions.

NONFERROUS METAL	CORROSION RATE OF NONFERROUS STRIP, Mils/Yr.	
	Coupled to Steel	Uncoupled
Copper	0.08	0.01
70-30 Brass	0.29	0.03
Nickel	<0.01	<0.01
Monel	<0.01	0.01
Aluminum 24ST	<0.01	<0.01
Aluminum 3S	<0.01	<0.01
Cadmium	5.8	0.46
Zinc	2.1	0.59
Solder (50 Pb, 50 Sn)	1.1	0.22

Steel was the cathode in every couple and showed very little weight change. Uncoupled steel showed no visible signs of corrosion (rate <0.01 mils/yr.).

Results from a group of corrosion tests in Dichan solution with galvanic couples, one element of which was a nonferrous metal and the other element steel, are summarized in Table X. Although steel was the cathode in every couple, corrosion rates of the nonferrous anodes were not increased to significant levels except for cadmium, zinc and lead-tin solder. It is noted that corrosion rates of the uncoupled nonferrous metals were lower under these stagnant conditions than those in Table IX.

Experience and laboratory tests have shown that in those cases where nonferrous metals show less corrosion in aqueous solutions of Dichan than in water, decreased corrosion is also noted in the presence of Dichan vapor relative to moist air without Dichan. For those metals corroded more by aqueous Dichan than by water, corrosion by Dichan vapor may be greater or less than corrosion by ordinary moist air. Highly variable results are obtained when vapor phase corrosion tests are made, the results depending greatly on conditions that normally would be taken as minor variables. Simple general statements summarizing such behavior cannot be made. The graphical summary in Figure 12 indicates the nature and range of results with a few important nonferrous alloys as observed in several extensive tests. In this graphical summary the effects on metal surfaces are given in qualitative terms. Surfaces with slight or even moderate stain or tarnish would not be considered impaired unless surface finish were critical. Control tests without Dichan were made in every storage series.

It is seen that a large spread of results was obtained, especially with aluminum 24S, brass and copper under contact conditions. Deleterious effects on the nonferrous metals tested were reduced or did not occur when the metals were not in direct contact with the Dichan coating. In a test with plated steel Dichan prevented rust, whereas all control specimens rusted at cut edges and at pin-holes in the plate.

Effects on Nonmetallic Materials

Specimens, most of which were sheets about 3 by 5 inches, were suspended from heavy wire racks stacked in a 50-gallon steel drum fitted with a loose cover. The drum was lined with paper containing 1.22 g Dichan per sq. ft., which also was interleaved between the racks. Approximately 72 sq. ft. of this paper was used, thereby providing about 12.5 g Dichan per cu. ft. The drum was stored in an unheated warehouse with an average temperature of about 60 degrees F for 24 months. At the end of this period analysis showed that the paper contained 1.14 g Dichan per sq. ft.

Specimen examinations involved comparison with a piece of the same material which had been stored in the same location in the absence of Dichan. The changes observed therefore are beyond those that might occur in normal storage. The comparisons were qualitative with respect to appearance, color, scratch resistance, tear resistance, etc.

Materials tested included 41 plastics, 29 protective coatings, 7 rubbers, 14 fabrics, 14 woods, 23 adhesives, 25 papers, 9 inks, 4 leathers and 4 gasket compositions. Marked deterioration was observed on only one type, films of rubber hydrochloride. Mild effects, indicating changes other than color and which might be progressive with much longer time exposure, were detected on one formulation of Koroseal, of Tygon and on a cellulose nitrate film. The remainder of the materials showed no effects aside from a few on which minor color change occurred.

Durability

For practical applications of Dichan as a corrosion inhibitor, information regarding the life expectancy of the compound under various conditions is important, especially in protective packaging applications. It has already been shown that protection may be expected only as long as Dichan is present in a

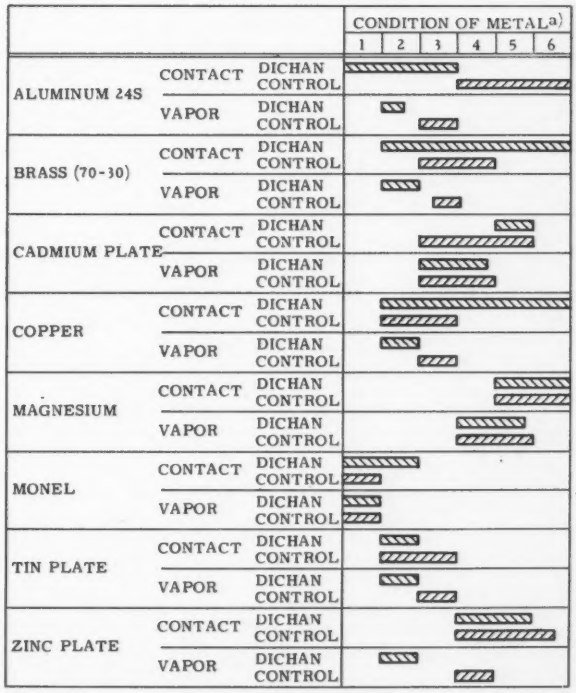


Figure 12—Effects of Dichan paper on nonferrous metals. a) 1—no change. 2—slight dulling, stain or tarnish. 3—dulling, stain or tarnish. 4—heavy tarnish or slight surface attack. 5—moderate corrosion. 6—corrosion or pitting.

package and that durability of at least five years was observed in outdoor exposure of packages.

Loss of Dichan from a package will be determined by its thermal stability, the extent to which the compound reacts with other materials in a package, the rate of vapor loss, and the extent of leaching by liquid water. In view of the solubility of Dichan in water it is apparent that rapid depletion of inhibitor may occur if liquid water in appreciable amounts enters the package, comes in contact with the Dichan, and subsequently drains out of the package. Localized depletion of Dichan paper at an area where the inhibitor paper is in contact with a steel surface would lead to rusting at that spot. This can be avoided by proper package design as required by expected exposure conditions, principally to prevent entrance of liquid water.

Vaporization Losses

Slow loss of Dichan may also occur by vaporization of the compound and would be influenced by temperature, wind velocity and the presence of barrier wrappings. Owing to the very low vapor pressure of Dichan such losses are very low in the absence of air currents sweeping directly over the inhibitor crystals. Protection against air currents is easily obtained by over-wrapping with an extra layer of paper, by placing in a cardboard box or corrugated paper board carton or by overwrapping with waxed paper, or with laminated papers containing asphalt or plastic film or metal foil. The last-mentioned group of barrier wraps provides especially effective means of minimizing vapor loss, and hermetic sealing of such overwraps is not normally required.

The rate at which vaporization of Dichan occurs at room temperature is shown by results given in Figure 13 from experiments in which sheets of Dichan paper were suspended in an air stream flowing at constant velocity over both sides of each sheet. It is seen that a sheet containing 1 gram Dichan per square foot would be depleted in about three weeks under these conditions.

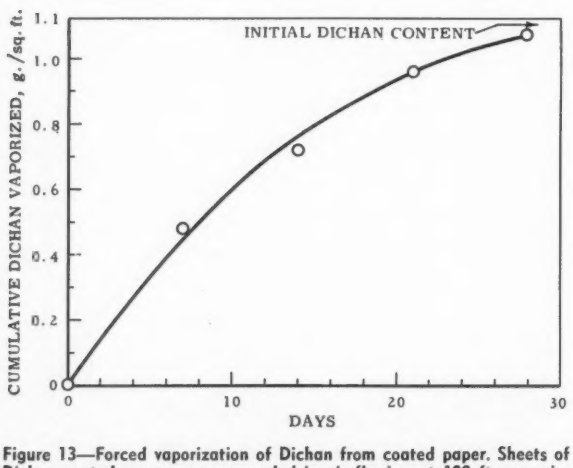


Figure 13—Forced vaporization of Dichan from coated paper. Sheets of Dichan coated paper were suspended in air flowing at 100 ft. per min. over both sides of each sheet, at room temperature (*ca* 70° F). Amount of Dichan remaining determined by analysis of portions of paper for nitrite.

Thermal Stability

Experiments have been made with the purified compound to determine stability as a function of temperature. Accurately weighed quantities of Dichan were placed in glass tubes which then were flame sealed and stored at different constant temperatures for extended time periods, after which the contents of each tube were analyzed for nitrite. Results calculated as time for complete decomposition (initial quantity divided by quantity decomposed per year) are plotted as a function of temperature in Figure 14. Although the pure compound is remarkably stable, the presence of materials such as some paper carriers that react with the inhibitor can cause reduced stability. For example, at 100 degrees F a life of about 25 years is indicated by Figure 14, whereas on kraft paper at a concentration of 1 g per sq. ft. a life of two years is found.

Storage Stability of Dichan Paper

Analysis for nitrite content of a variety of different preparations (30) of Dichan coated and impregnated papers (mostly kraft), which had been stored separately in waxed paper envelopes in a closed box in the laboratory (*ca* 72 degrees F) for periods from one to three years showed an average loss of Dichan content of 0.063 grams per square foot per year. On the basis of a linear relationship of loss with time, it appears that paper containing one g Dichan per sq. ft. would be exhausted under these storage conditions in 15 to 16 years.

It is known that amine nitrites are decomposed by acids or caustic alkalies in aqueous solution. The main products from reaction of Dichan with acid would be the nitrosamine and with caustic would be the free amine and sodium nitrite. Although commercial papers frequently contain weakly acidic constituents no consumption of Dichan was observed when such a paper was placed in contact with a diluted coating solution of Dichan (Table XI).

Stability in Solutions

Excellent stability was found in experiments (see Table XII) with solutions of pure Dichan in water stored at 100 degrees F and with identical solutions maintained in contact with steel.

Indications were obtained that the stability of Dichan in solution decreases in solvents less polar than water. However, the presence of a low concen-

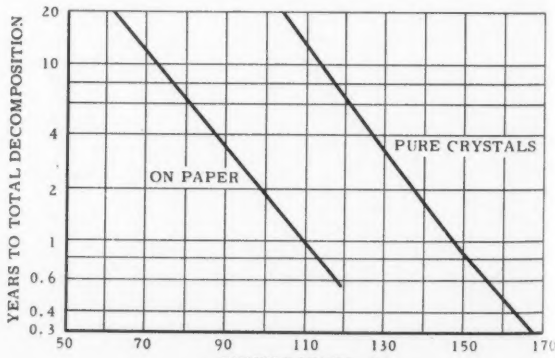


Figure 14—Thermal stability of Dichan.

TABLE XI—Dichan Consumption by Acidic Papers

One sq. ft. of a paper (ca 5 g) cut into small pieces and stirred into 400 ml of paper coating solution containing 1.05 g Dichan. Stored in stoppered flask at room temperature. Dichan content determined by colorimetric analysis for nitrite.

PAPER	pH of Water Extract of Paper	Dichan Content of Solution After 30 Days, g./400 ml
None	..	1.05
Kraft	5.6	1.05
Kraft	6.6	1.05
Sulfite	4.9	1.05

TABLE XII—Stability in Water

Ten ml of solutions of Dichan in distilled water were sealed in small glass test tubes. In another set of tubes polished steel strips (½ by 2 inch) were also inserted, the solution completely covering the steel. The tubes were maintained at 100° F. for different time intervals after which their contents were analyzed for nitrite.

DURATION, Hour	PERCENT OF NITRITE REMAINING	
	Dichan Solution Alone	Dichan Solution With Steel
	0.5% Dichan Solution	
500	97.0	98.0
1000	90.0	96.2
2000	80.0	42.0
	1.0% Dichan Solution	
500	94.1	97.6
1000	87.3	93.8
2000	84.9	89.8
	2.0% Dichan Solution	
500	90.8	95.5
1000	93.0	95.5
2000	91.4	94.7

tration of dicyclohexylamine in such solutions exerts a strong stabilizing influence. For example, a 1 percent solution of Dichan in an 88 percent isopropanol-12 percent water solvent sealed in a glass tube and stored for 300 hours at 150 degrees F lost 72 percent of its content, whereas with 0.01 percent dicyclohexylamine also present the loss was only 4 percent.

Light Stability

It was observed that samples of pure white crystals of Dichan stored in clear glass bottles and exposed to diffused daylight in the laboratory would slowly darken superficially. Experiments in which small quantities of the inhibitor in sealed glass tubes were exposed to direct sunlight for 60 days, showed that such exposure caused marked decomposition (20 to 50 percent) even when dicyclohexylamine was added.

Protection Life of Dichan Packages

Data were obtained from a very large number of tests made to determine the durability of Dichan in a variety of packages with many different types of barrier overwraps in different natural locations for storage periods up to three years. Losses of Dichan were measured by periodic analyses for nitrite remaining on the Dichan paper employed as inner wrapping in these packages; thus these include losses both by vaporization and by decomposition. A rather wide spread of results was obtained so that in summarizing results, as given in Table XIII, it was necessary to estimate a range of protection life for each packaging system.

All tests were made with Dichan paper initially containing 1.0 gram per sq. ft. It was assumed that protection was maintained until the Dichan concentration declined to a value of 0.10 gram per sq. ft. This assumption is in general agreement with corrosion observations. Many values for lives were obtained by extrapolation on the established basis that loss of Dichan is linear with time. All life values greater than 36 months were obtained by extrapolation.

Duration of protection in shelf storage was determined with isolated, unstacked packages stored on shelves in various indoor areas. Storage temperatures were in the range of 55 to 70 degrees F, and average wind velocity less than one mile per hour.

Duration of protection in outdoor exposure was obtained with isolated unstacked packages stored in open shelters with protection from direct rain. Wind velocities ranged from 3 to 10 miles per hour and the average storage temperature was approximately 55 degrees F (average winter minimum 40 degrees F and average summer maximum 70 degrees F).

Data were obtained with several different types of barrier materials, differing in base weight of paper, wax and asphalt and in thickness of cardboards, films and foils. The spread of results for a given barrier was found to be greater than effects of base weight or thickness of film, although slight indications of longer life were noted with thicker barriers and heavier loading of wax or asphalt.

At low temperatures (<75 degrees F) and with good barriers the losses observed were very low even in tests run for as long as three years. Frequently such losses were about equal to the experimental error.

The effect of initial Dichan content on life is essentially linear; double the life being obtainable at a concentration of two grams compared to one gram per sq. ft.

Life values for Dichan paper plus a separate barrier sheet are significantly greater than for Dichan applied directly to the barrier sheet.

The effect of air flow is quite marked as shown by comparison of indoor and outdoor storage lives. Since it is unlikely that individually wrapped parts would be exposed outdoors as single units for prolonged periods, indoor storage lives are of greater practical significance.

When trivial or zero vaporization loss of Dichan can occur, e.g., in storage of rolls of Dichan paper stock or when perfect barriers are employed in sealed packages, lives of about 180 months would be ex-

TABLE XIII—Protection Life of Dichan Packages

PACKAGE COMPOSITION		MONTHS PROTECTION	
Dichan Carrier	Outer Barrier	Shelf Storage Indoors (Wind <1 Mile/Hr.)	Open Shed Storage Outdoors (Wind 3–10 Miles/Hr.)
Kraft paper	None	10–14	.....
Waxed kraft	None	24–48	12–18
Kraft-asphalt-kraft	None	24–60	12–30
Cardboard	None	12–18	8–12
Waxed cardboard	None	24–60	15–24
30-lb. kraft	Kraft paper	15–24	3–15
30-lb. kraft	Cardboard	15–30	9–21
30-lb. kraft	Waxed kraft	75 to > 120	24–54
30-lb. kraft	Kraft-asphalt-kraft	75 to > 120	36–60
30-lb. kraft	Waxed cardboard	75 to > 120	24–54
30-lb. kraft	**Films:** moisture-proof cellophane, Pliofilm, Saran, Koroseal, Ethocel or polyethylene	60 to > 120	.....
30-lb. kraft	Metal foils or laminates	90 to > 120	90 to > 120

TABLE XIV—Package Protection Life as a Function of Temperature

Average Temperature, °F.	Overwrap, 20-Lb. Wax on 45-Lb. Kraft
	(Months)
55–60	75 to > 120
65–75	42 to > 120
85–95	36–72
100	21

pected at temperatures of 65 to 75 degrees F and of about 24 months at a sustained temperature of 100 degrees F. Lives shown in Table XIV for several temperatures would be expected with a less than perfect barrier over-wrapping 1.0 gram Dichan paper in isolated packages stored indoors with ½ to 2 miles per hour air movement over them.

Protective Packaging Method

The fact that a slightly volatile corrosion inhibitor can be made an integral part of packaging materials, such as Dichan-coated wrapping paper, makes possible a distinctive and often highly advantageous method of corrosion preventive packaging for metals. The inhibitor can be used in many types and variations of packaging procedures, selection of which will depend on the article to be packaged, corrosive conditions that the package is likely to encounter, duration of protection desired, and cost factors.

One type of procedure involves merely wrapping the steel article in the inhibitor paper, with a barrier coating on the outside to hinder escape of the inhibitor and ensure long-term protection. In such instances a wax-coated inhibitor paper or kraft-asphalt laminated inhibitor paper may be employed. Simple fold closure of such packages usually is adequate. If a barrier film is not incorporated in the inhibitor paper, a separate overwrap sheet of barrier paper or a box container is employed. Suitable barrier overwraps would be waxed paper, kraft-asphalt-kraft paper, or metal-foil laminates.

In many instances of paperboard-box or corrugated-paperboard-carton packaging the inner wrap with inhibitor paper may be eliminated. Instead, it may be preferable to use a case liner of inhibitor paper. When many individual items are to be packaged in a single box it may be advantageous to use separators of inhibitor paper instead of individual inhibitor paper wraps around each of the items. Even greater simplification of packaging operations is possible if the box is fabricated of paperboard with the inner surface coated with inhibitor.

One of the simplest procedures involves use of an envelope or bag prefabricated from inhibitor plus barrier paper. The article then simply is placed in the envelope, and the flap turned down and fastened by clips, staples or adhesive.

In using volatile inhibitor packaging methods, it must be remembered that when a bare steel article is removed from its package it is no longer being protected. The article must be replaced in the package if continued protection is desired.

In general, the main guiding principles for effective use of the method are as follows:

1. The inhibitor coating should be placed relatively close to the metal surfaces to be protected. This requirement usually is met automatically by wrapping the article in inhibitor paper.
2. The innermost surface of the package should contain the inhibitor. Uninhibited dunnage, blocks or wrapping materials should not be interposed between the inhibitor and the metal.
3. Any air which may enter a finished package should be compelled to pass through or over the inhibitor before it reaches a bare steel surface.
4. A barrier wrapping or film should be provided in order to hinder vapor loss of the inhibitor so that protection may be maintained for a long period.

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Publication 51-3

Stress Corrosion Cracking in Alkaline Solutions

Technical Practices Committee 5 C — *Sub-Surface Corrosion by Alkaline Solutions*

By H. W. SCHMIDT,[1] P. J. GEGNER,[2] G. HEINEMANN,[3] C. F. POGACAR,[4] and E. H. WYCHE[5]

Abstract

A discussion is presented of the results of an industry survey on the failure of materials in alkaline solutions. Most of the data have to do with sodium hydroxide. The relationship of temperature and concentration to cause failure can be expressed only in an approximate manner. Corrective measures that have been employed to eliminate failure are discussed.

Introduction

AFTER TECHNICAL Practices Committee TP-5 was formed to investigate corrosion problems involved in processing and handling chemicals, Subcommittee TP-5C was given the problem of studying caustic embrittlement. The official title of the sub-committee's subject is "Subsurface Corrosion by Alkaline Solutions." The phenomenon of caustic embrittlement is an old one and is usually associated with the cracking of boilers around rivet holes. The incrustation present at the crack was always observed as strongly alkaline in nature. Hence, the term caustic embrittlement. The choice of this title was unfortunate inasmuch as the term implies an embrittlement of the metal itself which is certainly not the case, even though the presence of the cracks make it appear otherwise. The present terminology for this type of failure is stress corrosion cracking in alkaline solutions. A great deal of research has been done and publicity has been given the problem as regards the power industry. However, the problem has received little publicity as it is encountered in the chemical and process industries. The purpose of this report is to present information that has been obtained from the chemical and process industries on the failure of materials in alkaline solutions.

Theory

At the 1950 annual meeting of the NACE, J. J. Harwood[1] presented an excellent paper on the problem of stress corrosion cracking of metals in general. A very complete bibliography was appended. Attention is also directed to the paper "Stress Corrosion Cracking In Mild Steel"[2] by J. J. Waber and H. J. MacDonald. In addition to a review of the fundamentals, Harwood also discussed the theories of stress corrosion cracking:

A. The electrochemical theory proposes that two conditions must prevail: 1) the internal structure of the metal must be such that a susceptibility exists for the formation of small anodic areas and; 2) there must exist a condition of high stress acting in a direction tending to pull the metal apart along continuous paths. The small anodic areas corrode as continuous paths. A sharp notch is formed which causes a high stress at the base. The high stress produces a tearing apart of the metal thereby exposing fresh anodic material. The cycle continues in this manner.

B. The film theory follows along the same lines except that the anodic areas are produced at points of film weakness; e.g., grain boundaries. Once a notch is formed, stress causes a rupture of the film with more anodic area exposed.

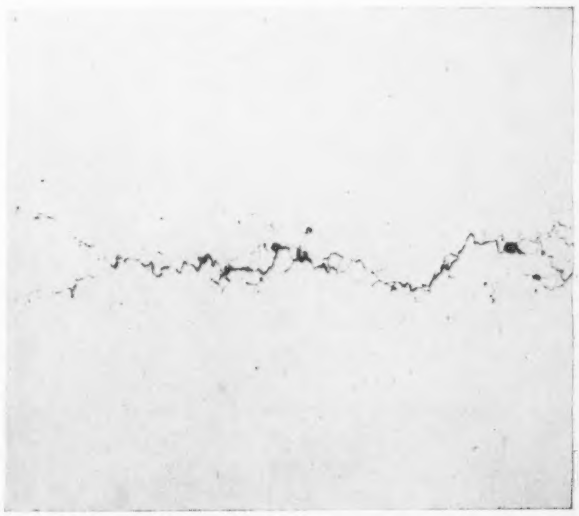

Figure 1—Stress corrosion crack in mild steel at 75x unetched.

★A report of National Association of Corrosion Engineers' Technical Practices Committee 5C—Subsurface Corrosoion by Alkaline Solutions. Prepared for and presented at the NACE Seventh Annual Conference and Exhibition, New York, N. Y., March 13-16, 1951, by H. W. Schmidt, Chairman TP 5C.

1. The Dow Chemical Company, Midland, Michigan.
2. Columbia Chemical Division, Pittsburgh Plate Glass Company, Barberton, Ohio.
3. Southern Alkali Corporation, Corpus Christi, Texas.
4. Koppers Company, Inc., Pittsburgh, Pennsylvania.
5. Lukens Steel Company, Coatesville, Pennsylvania.

TABLE I—Summary of Data Given in the Questionnaires on Caustic Solutions

Ref. No.	Equipment and Construction	Material	Conc., Percent	Temp. °F.	Time to Failure	REMARKS
1	Drums, Towers, Piping.....	A70 and A53.....	2½	Atmos.	No Failure	Hydrocarbon vapor present.
2	Still, Towers, Shell and Tube Exchangers	A70 and A53, A106 Type B	2½	Up to 1200	No Failure	150 lbs. of 4° Be Caustic in 18,000 Bbl. Crude Oil.
3	Pipe from Single Effect Evaporator	Steel	5	190–200	5 Years +	Failure near welds. Judged material embrittled when it could not be welded. Rewelding not successful. Caustic entrained in vapor from evaporator.
4	Scrubber Tower	A70	5	100 Max.	No Failure	Sulfides in hydrocarbon vapor.
5	Pipe, Thickeners, Wash Tanks	Steel	10	160	No Failure	No cracking in 10-12 years.
6	Pipe, Thickeners, Wash Tanks	Steel	10	180	No Failure	No cracking in 10-12 years.
7	Scrubber	A70 Plate	10	65–100	No Failure	Na_2SO_4, complexes of $(NH4)_2SO_4$. Traces of each in hydrocarbon vapors.
8	Evaporator Tubes Expanded	Swedish Charcoal Iron	10	270	See Remarks	Only 1% of tubes failed in 10 years. Cracking occurred in rolled area principally at extreme depth of roller insertion and at upper ends.
9	Bubble Tower, Scrubber Tower Piping	Monel Metal Plates and Liners, Copper Piping, Karbate Trays	10	210	No Failure	No failures.
10	Welded Storage Tanks	A70	11	149	No Failure	No failure after 14 years.
11	Evaporator Tubes Expanded	Charcoal Iron	10–15	150	No Failure	OK after 8 years.
12	Evaporator Tubes Expanded	Charcoal Iron	10–15	150	No Failure	OK after 5 years.
13	Pipe, Thickeners, Wash Tanks	Steel	15	160	No Failure	No cracking in 10-12 years.
14	Storage Tanks—Welded	A10	15	150	2 Years	Failure at points of stress such as around manholes, where clips are welded to outside, etc. Changes in design to reduce stress concentration have increased life, but failures still occur. Caustic is by-product of sodium reduction process for making fatty alcohol. Water, small amounts of xylene and toluene are present.
15	Soap Making Kettle—Welded	A285 Grade C	15	240	10-15 Yrs.	Failure at knuckle radius of cone bottom and in seams. Bottom seams cracked first; double butt welded seams and ASME knuckle radius on heads improves life.
16	Expanded Tubes	5% Ni Steel	10–20	200	8 Months	Cracks were confined to ends of tubes which projected through tube sheet and were transcrystalline in nature. These cracks may have been due to corrosion fatigue.
17	Expanded Evaporator Tubes	Steel	16	180	.....	Cracking at ends of tubes.
18	Evaporator Tubes Expanded	Charcoal Iron	15–22	150	No Failure	OK after 15 years.
19	Welded Pipe	Carbon Steel	18–20	266	6 Months	Cracked at welds both in welding neck flanges and pipe joints. Replacement with nickel preferred.
20	Welded Tanks	Steel	20	130	No Failure	OK after twenty years.
21	Exaporator Tubes Expanded	Swedish Charcoal Iron	20	220	1 Year	Only 15% of tubes failed in 10 years before replacement. Cracking occurred in rolled area principally at extreme depth of roller insertion and at upper ends.
22	Expanded Tubes	5% Ni Steel	20	190	1 Year	Cracks in the expanded area.
23	Evaporator Tubes Expanded	Charcoal Iron	15–25	265	5 Years	In tubes just below tube sheet. Replaced tubes.
24	Pipe from Preheater	A106	25	250	5 Days	Failure adjacent to weld at point of maximum stress due to bending. 215 lbs. of 32° Be Caustic soda in 100 Bbls. of crude oil.
25	Welded Storage Tanks	A70	25	140–212	4 Years	Cracks at girth welds. Replaced with nickel clad steel.
26	Formed Angle	Steel	20–30	165	.....	Angle formed by bending plate cold. Cracks in groove of bend.
27	Welded Plate	Steel	20–30	165	26 Mo.	Cracks parallel to weld.
28	Evaporator Tubes Expanded	5% Ni Steel	26	180	1 Year	Cracks in expanded area of tube. Cracks repaired by welding.
29	Welded Pipe	Steel	28	190	10-15 Days	Parallel to and ¼ to ½" away from welds made in field. Replaced with threaded joints, but these leaked after 2-3 months. Final replacement with nickel OK after 10 years.
30	Evaporator Tubes Expanded	Charcoal Iron	28	140	No Failure	No cracking. Tubes failed by corrosion.
31	Salt Separating Tank, Welded	Ni Clad Steel	20–35	160	8 Years	Failures adjacent to welds. Chipping and rewelding no good. Welding wide strips over welds OK. Spraying nickel over weld OK. Contains 1-25% NaCl.
32	Settling Tank—Welded	Steel	30	176	3 Years	Transverse cracks in welds in tank sides and around bottom outlet. Similar cracks around bottom welds after 4 years more. Repairs by welding no good. Sides eventually replaced by Ni Clad Steel and liner of nickel in bottoms, around outlet.
33	Expanded Evaporator Tubes	Toncan Iron	30	190	See Remarks	Total life 3 years before replacement. Cracked in rolled area at extreme depth of roller insertion.
34	Expanded Evaporator Tubes	Domestic Charcoal Iron	30	190	See Remarks	Cracked in rolled area at extreme depth of roller insertion. Total life 2½ years before extent of failure necessitated complete replacement. Will replace with nickel.
35	Expanded Evaporator Tubes	Swedish Charcoal Iron	30	220	6 Months	Cracked in rolled area at extreme depth of roller insertion, only 20 percent of tubes failed in 9 years before replacement.
36	Riveted Tank	Steel	32	140	No Failure	Tank was welded around rivets and is OK after 8 years.
37	Welded Tanks	Steel	32	140	No Failure	No failure after 15 years.
38	Welded Piping	Steel	32	140	8 Years	Failure around welds. Section removed and rewelded.
39	Riveted Tanks	Steel	32	140	No Failure	OK after 20 years.
40	Welded Tank	Steel	32	140	7 Months	Badly cracked. Patching not effective. Replace with 3½% Ni Steel. OK after 2 years.
41	Evaporator Tubes Expanded	5% Ni Steel	32	140	1 Year	Cracks in expanded area of tube. Seal welded crack OK. 32 tubes replaced in 2 years. Still operating after 9 years.
42	Evaporator Tube Sheet	5% Ni Steel	32	140	1 Year	Tube sheet cracked after welding in new pump well. Cracks repaired by welding.
43	Riveted Dissolving Tank	Steel	10–45	150–200	See Remarks	Life of tank 20 years. Apparently tank cracked before this and was patched by welding. As cracking spread this method was no longer successful.
44	Riveted Dissolving Tank	Steel	10–45	150–200	See Remarks	Tank life 20 years. Apparently earlier cracks were repaired by welding large patches. Chipping and welding cracks no good.
45	Welded Pipe	Steel	35	160	Few Weeks	Cracks generally normal to weld.
46	Welded Storage Tank	Steel	50 20–35	100 200	10 Years	Tank used alternately on service indicated. Failure adjacent to welds. Chipping and welding cracks no good. Welding patch strips over leaks no good. Tank scrapped.
47	Flohead Nuts & Studs on Floating Head Exchanger	A-194-46 Class 2H, A-193-46, Class B7	41	130–225	2 Years	Axial cracks in nuts. Transverse cracks in studs. Changed to Monel Metal. Satisfactory. 81% of 45° Be Caustic Soda, 17% Methanol, remainder Methyl and Ethyl Mercaptan.
48	Welded Pipe in Evaporator Circulating Line	Steel	48	130	10-12 Months	Failure in welds. Replaced with Nickel. OK after ten years.
49	Storage Drums, Piping and Pumps	Steel	Up to 50	130 Max.	No Failure	No cracking.
50	Forge—Welded	Steel	50	160 Max. 120 Avg.	5 Years	Tank was used a long time in other service before transferred to caustic service. 5 years on caustic. Cracked where steam heating coils enter drum. Also knuckle radius of 1 head. Rewelding made cracking worse.
51	Welded Storage Tank	ASME S-1 Hot Rolled	50	60–300	10 Years	Tank annealed after fabrication. Failure at steam nozzles after ten years. Repaired crack by welding without re-annealing. Failure in 1 week. Repaired by rewelding and local anneal at 1200 °F. Metallized areas with steel. No failure in five years.
52	Welded Storage Tanks	ASME S-1 Hot Rolled Annealed	50	122	3 Years	Cracked at tank supports. Cracks repaired by welding, supports increased locally, stress relieved, metallized with steel. No further failure after 4 years.
53	Evaporators—Welded	Flange Quality Steel	50	212	2-5 Years	Cracked at welds in nozzle carrying heater. Contained 98% iso propyl alcohol.

TABLE I—Continued

Ref. No.	Equipment and Construction	Material	Conc., Percent	Temp. °F.	Time to Failure	REMARKS
54	Welded Storage Tank	Steel	50	180 Max. 100 Avg.	1 Year	Man ways and reinforcing flanges only were stress relieved Longitudinal and transverse cracks in vertical weld of shell and in welds of reinforcing pads to shell and in coil support welds. Rewelding not practical. Will specify stress relieving.
55	Welded Tank	Steel	50	70-200	2 Years	Cracked in welds. Riveted tanks have been in this service 10 years satisfactorily. Recommended riveted or annealed steel tanks, not field welded.
56	Welded Storage Pot	Steel	50	250 Max. 200 Avg.	2 Months	Cracks in welds in cone bottom. Could not repair by welding. New tank was lined with caustic resistant lining.
57	Welded Measuring Tank. Externally Heated	Steel	50	100 Sol. 300 Heating Coil	1 Year	Cracked in welds at point of contact with heating coil on bottom of tank. Cracked section removed and heating coils lowered to give 1½ inch air space.
58	Welded Caustic Stripper Column	A70 Firebox	50	300 At Bottom	6 Months	Bottom part of Tower Ni Clad. Cracks in steel plate near weld to Ni Clad plate. Steam at 800 °F. added to tower through nozzle. This nozzle cracked in weld. Rewelding not successful. Strip lining with Monel and stress relieving not successful. Other constituents include 1-2% Na_2SO_4 and 0.2% Mercaptan Sulfur.
59	Welded Tank	Steel	50	150	6 Months	2″ steam coil through 6″ neck. Cracked in welds around neck. Failure believed due to poor circulation in neck and overheating. Eliminated neck and controlled temperature.
60	Welded Rectangular Storage Tank	Tank Steel	50	230	3 Days	In service 3 years at 120 °F. with no failure. Raised temperature to 230° and cracking started parallel to welds. Dropped temperature to 120 °F. and cracking stopped. Increased temperature was due to diluting 72% Caustic. Installed Nickel caustic cooler.
61	Welded Tanks and Pipe Lines	Steel	50	120	Over 1 Yr.	Failure in welds. Rewelding not successful.
62	Welded Pipe	Steel	50	See Remarks	2 Years	Cracks in bends of heating coil using 150 psi steam. Design changed and welds stress relieved. Coil supported to reduce stress.
63	Welded Pipe	A53	50	180 Max.	4-12 Mo.	Failure around welds. Reduced concentration 25%. No failures.
64	Welded Tanks and Piping		50	100	No Failure	No failures in tanks or piping.
65	Pipe and Tanks	Steel	50	125 Max.	No Failure	No failures in piping after 10 years or in tank after 3 years.
66	Welded Tank	Ni Clad Steel	50	176	10 Years	Cracking in nickel clad welds. Nickel butt straps OK after 6 years.
67	Welded Piping	Steel	50	180	No Failure	No failures.
68	Welded Tanks	Steel	50	180	No Failure	No failures after 8 years.
69	Riveted Tanks	Steel	50	180	No Failure	No failures after 35 years.
70	Tank Cars	Steel	50	232	No Failure	Cars are filled with caustic heated to 248 °F. and allowed to cool in transit. Both riveted and welded tanks used. Tanks are lined with caustic resistant coating.
71	Welded Tank	Steel	50	180	2½ Years	Around welds. Welded patches. Still in service after 8 years. Patched periodically.
72	Welded Piping	Steel	50	?	Varies	Lines steam traced with 150 lb. steam. Temperature of pipe unknown. Lowering steam pressure to 30 lb. increased life. Cracked areas are cut out and new section welded.
73	Expanded Evaporator Tubes	Toncan Iron	50	220	See Remarks	Cracking occurred in rolled area, principally at extreme depth of roller. Total life 2-3 years before extent of failure necessitated replacement.
74	Expanded Evaporator Tubes	3½% Ni Steel	50	220	6 Months	Cracking occurred in rolled area, principally at extreme depth of roller. Complete replacement with nickel.
75	Welded Storage Tanks	A70	50	104	No Failure	All small tanks are stress relieved. Field erected large tanks are not stress relieved. No failure in large tanks in 15 years.
76	Welded Storage Tanks	A70	50	194	4 Years	Cracks at welds. Replaced with nickel clad steel.
77	Expanded Evaporator Tubes	"A" Nickel	30% NaOH 50% KOH	220	No Failure	No failures.
78	Riveted and Welded Tanks	Steel	1-70	100-150	.....	No failure.
79	Welded Tank	A10	50-73	220 Max. Occasionally	6-12 Mo.	Used to dilute 75% Caustic to 50%. Failure in welds. Now diluted to 25%, temperature Max. 200, about once a month. Tank OK after 9 years. Previous experience indicated riveted tanks last 3-4 times as long as welded tanks.
80	Welded Tanks and Pipe Lines	Steel	73	180-200	2-3 Wks.	Failure in welds. Rewelding not satisfactory.
81	Welded Storage Tank	A265 Ni Clad Steel	70	180	6 Mo.	Failed at welded joints. Improved welding and inspection to insure sound weld.
82	Piping Welded	Steel	75	140	No Failure	No failures.

C. The mechanical theory agrees with the electrochemical theory in the initiation of the crevice. Crack propagation is purely a function of the stress tending to tear the metal apart.

D. The strain accelerated decomposition theory postulates that the principal function of stress is to generate precipitation reactions, phase transformations, and order-disorder reactions which provide the necessary anodic paths for corrosion. Incipient cracks form from surface inhomogeneities and, once formed, continue to grow by the following mechanism: The stress concentration at the apex of a crack causes the metastable parent phase to decompose faster in this vicinity than in the bulk of the metal. One of the decomposition products is anodic to the parent matrix and is corroded away by the medium. As a result the crack grows, forming new anodic material ahead of it in its path.

A stress corrosion crack in a specimen from a steel tank is shown in Figure 1. (Reference No. 40, Table I.) The tank failed after seven months in 32% caustic at a temperature of 140° F. The characteristic branching of the crack is readily apparent. Figure 2 is the same area with the steel etched. It is evident that the crack in this typical low carbon steel is intergranular in nature. Figures 3 and 4 are micrographs of the same fields as 1 and 2 respectively except that the magnification has been increased to 500X. This is an example of a particularly severe case of cracking in that there is present a multitude of branching cracks. More often a crack will consist of a single spine with only an occasional branch.

Service Experience

In order to collect data on service experience in handling alkaline solutions a questionnaire was circulated among the chemical and process industries. Although the response was gratifying, the committee believes that there is much more experience available if it can only be gathered. The questionnaire did not specifically limit the desired informa-

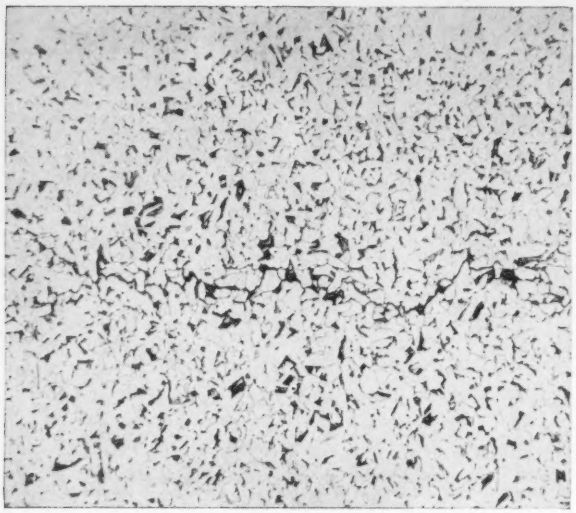

Figure 2—Stress corrosion crack in mild steel at 75x. Etched with 2 percent nital, 1 percent picral.

Figure 3—Stress corrosion crack in mild steel at 500x unetched.

tion to caustic soda and a number of replies were received which described failures of materials in alkaline solutions other than caustic. The data received describing experiences with caustic are arranged in Table I in increasing concentration of caustic. The data describing experiences in alkaline solutions other than caustic are included in Table II.

The tables show the kind of equipment used, type of construction, material of construction, concentration of the caustic, temperature of the caustic, time to failure, and remarks. The headings are self-explanatory. There was some uncertainty in several cases as to whether the temperature given was that of the metal or that of the solutions in the units. Several of the failures in the lower temperature range were questioned in this regard. In only one case was a reply received stating definitely that the temperature given was that of the metal. No replies having been received in the other cases the temperatures were assumed as being that of the metal.

In the column, "Time to Failure," the statement "no failure" was used to indicate that no failure was experienced during the service life of the equipment as given under the "remarks" column. In a few cases this information was not included in the questionnaire. The column headed "remarks" may also

TABLE II—Summary of Data on Alkaline Solutions Other Than Caustic

Ref. No.	Equipment and Construction	Material	Corrodant	Temp. °F.	Time to Failure	REMARKS
83	Drier	Type 316 Clad Stainless Steel	KCl pH 7.3-7.6	250–300	10-12 Mo.	Severe embrittlement of cladding in a well defined area on interior of drier shell, 12-18 feet from discharge end. Applying gunite to area has been successful. Monel Metal has been successful in area.
84	Piping, strippers, absorbers, heat exchanger shells and heads.	A285C	15% Ethanolamine in water with H_2S and CO_2	Up to 300	6 Mo. to 10 Yrs.	Cracking at welds and in cold worked angle iron. Complete stress relieving satisfactory.
85	Digester	Steel	Sodium Aluminate liquor containing ground bauxite and lime	292	20-25 Yrs.	Cracking around rivet holes. Tank replaced with welded stress relieved tank.
86	Still	Type 347 Stainless Clad with 347 Coil.	NaOH, NH_3, and Ethylenedichloride	349° Sol. 376° steam in coil	2 Mo.	Longitudinal and transverse cracking at end and adjacent to welds. The vessel itself was only mildly affected after 6 months.
87	Centrifuge ploughs	Type 317 Stainless with Stellite edge.	Alkaline Na_2SO_4 Slurry	Ambient	11 Mo.	Cracking of stainless steel adjacent to Stellite due to carbide precipitation. Replaced with Type 316 Cb Stainless Steel.
88	Cooling Coil	Type 304 Stainless cold formed. not heat treated.	Treated water pH 8.0-8.5	60–385	4 Yrs.	Coil was held rigidly. Cracking took place at points of maximum stress. Recommended replacement with Monel Metal.
89	Condenser	Type 304 Stainless Steel	Alkaline Organic Solutions	302-392	2 Yrs.	Cracking in expansion joint of shell. Crack confined to bends and welds. Recommended Monel Metal.
90	Agitator	Type 304 Stainless Steel Casting	Neutral to Alkaline Na_2SO_4 Slurry	120-160	1 Yr.	Cracking of agitator blade at hub. Recommended Wrought Type 347 Stainless Steel and redesign.
91	Sparkler Filter	Type 304 Stainless Steel	Lime and Organic Solvents	221-266	7 Mo.	Cracking at radius of die formed elements. Recommended Type 347 Stainless Steel stress relieved or Monel Metal.
92	Evaporator Coil	Type 316 Stainless Steel cold formed.	Sodium salt of organic compound	212	1 Yr.	Myriad of cracks on outside surface of curvature in area under tension. Recommended heat treatment or use of Type 347 Stainless Steel and stabilizing treatment.
93	Condensers and Exchangers	Arsenical Admiralty Metal Tubes	Polluted sea water containing some ammonia compounds pH 8.0-8.5	104-302	5½ Mo. to 4 Yrs.	Cracking anywhere in tube between tube sheets.
94		Admiralty Metal	See Remarks	Up to 430	5-20 Mo.	Ammonia added to hydrocarbon stream to control pH 6-8. Cracks developed in cold worked areas. Installed steel tubes.

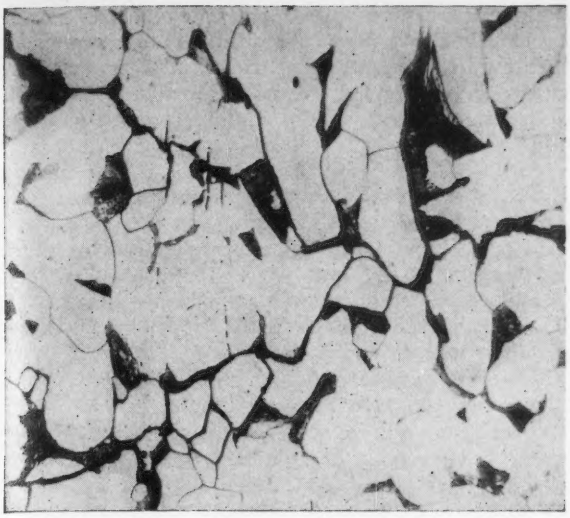

Figure 4—Stress corrosion crack in mild steel at 500x. Etched with 2 percent nital, 1 percent picral.

contain data on the location of the failure, the corrective measures employed, results of such corrections, and kinds and amount of any minor constituents that were present in the caustic.

Temperature and Concentration

In any discussion of stress corrosion cracking in alkaline solutions, the effect of temperature and concentration is usually considered. A plot of all the service data showing this relationship of temperature with caustic concentration is given in Figure 5. A curve was drawn approximately at the limit below which no failures were reported. This might be called a limiting temperature curve. In all probability the curve is quite conservative; however, before it could be raised, a detailed examination would have to be made of all the points of failure near it.

A. A. Berk and W. F. Waldeck[3] in a recent paper described the results of their tests in caustic soda solutions and gave what they call a "caustic danger zone" on a temperature-concentration plot, above which failure will occur. They used the conventional horseshoe specimen with the time of test varying from six to sixty-two days. Their data are reproduced in Figure 6. It will be seen that the "caustic danger zone" is located at a higher temperature than the limiting temperature curve in Figure 5, indicating that the latter curve may be conservative. On the other hand, the fact that the laboratory tests were run for a maximum of sixty-two days whereas the field data include many years of service, is also significant.

The service data were also plotted to study the effect of temperature on time to failure for given caustic concentrations. No significant correlation was found as shown in Figure 7 for the case of 50% caustic soda. It is of interest to note that producers in general recommend the storage of caustic solutions up to 140° F in as-welded steel tanks, but for higher temperatures welded tanks must be stress relieved.

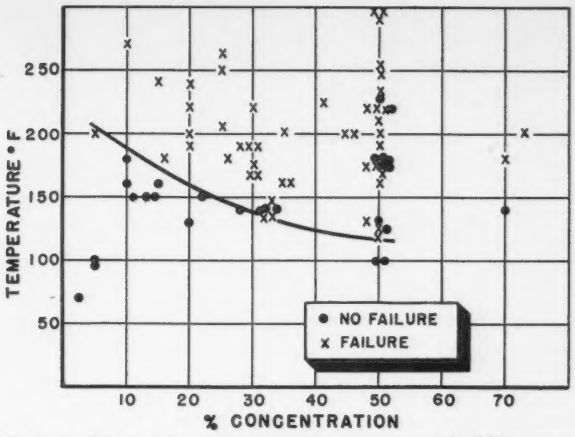

Figure 5—Relation of temperature and concentration of NaOH to cause cracking.

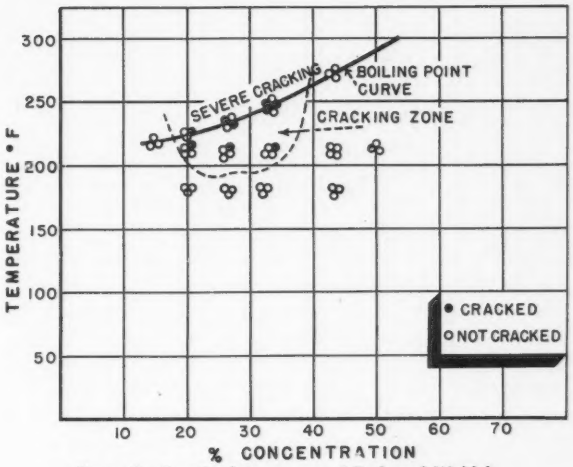

Figure 6—Caustic danger zone of Berk and Waldek.

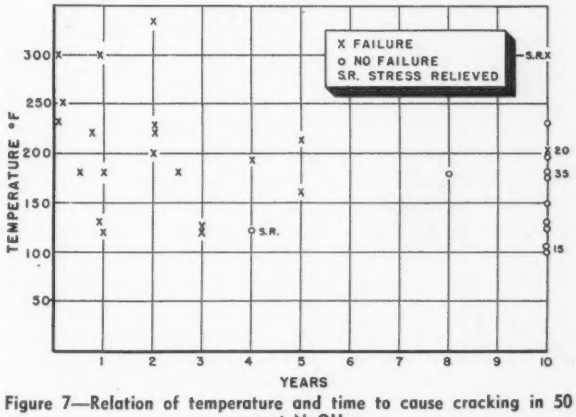

Figure 7—Relation of temperature and time to cause cracking in 50 percent NaOH.

Stress

Obviously, an important factor in stress corrosion cracking is stress. However, it is extremely difficult to evaluate stress conditions in industrial equipment, because of its complexity. Stresses usually include residuals introduced during construction as a result of welding, bending, forming, etc., as well as those

produced by virtue of the operating conditions through temperature, pressures, etc.

The data show that in many cases welding was responsible for producing stresses of sufficient magnitude to induce cracking. It is well known that welding can produce stresses in excess of the yield strength of a material. Other fabricating operations also responsible for cracking were the bending of tubes and expanding of tubes in tube sheets. How much can be done to lower fabricating stresses to a level where cracking cannot be induced is not known.

In the case of welding, bending, rolling, and other operations which deform the metal, residual stresses so produced can be materially decreased by stress relieving. A case in point can be cited in Reference No. 51, Table I. A welded steel storage tank was stress relieved before being placed in 50% caustic service at 60-300° F. Failure occurred after ten years of service. The crack was repaired by welding but not subsequently stress relieved. Failure again occurred in one week. This was then repaired by rewelding and followed by local stress relieving at 1200° F. The welded area was then metallized with steel. No failure was reported after approximately five years.

Stress relieving of shop fabricated vessels presents no problem and the cost is not prohibitive as insurance against failure. A real problem does exist in the case of field erected tanks and piping as well as repairs made in the field. There is great need for an adequate method of stress relieving in these cases. The so-called low temperature stress relieving method[4,5] may have some merit. This method advocates the heating of a narrow band of metal on each side of the weld to 350-400° F followed by rapid cooling with water. Theoretically this produces a localized stretching of the metal with a resultant decrease in stress. In the case of piping, a band around the pipe containing the weld is heated to 1100-1200° F and allowed to cool in air. Time has not permitted these methods to demonstrate that they will prevent cracking, however, the fact that stresses are reduced is of importance.

A method that has been used extensively to reduce fatigue failures is shot peening because such treatment induces a compressive stress on the surface of the material. It has been proposed that this technique be used as a method of preventing stress corrosion cracking since it is known that compressive stresses do not promote such failures. However, one point that should not be overlooked in the use of this method is the possible removal of the compressively stressed layer by corrosion. No data have been made available on the effectiveness of shot peening in decreasing stress corrosion cracking in caustice service.

Corrective Measures

A number of corrective measures were suggested by the contributors. These measures can be divided into three groups: 1) those affecting a decrease in stress level; 2) those affecting a decrease in temperature; and 3) those proposing some change in material.

Factors Affecting Decrease in Stress

Any change in design, construction, or operation of equipment resulting in a decrease of the stresses will be beneficial. As previously noted, both the residual stresses introduced during construction and the applied stresses during operation must be considered. Two examples are cited of design changes made to reduce stresses: 1) A welded steel storage tank (reference 52, Table I) in 50% caustic at 122° F cracked after three years. The failure was located at tank supports. The number of supports were increased and the area was locally stress relieved. No failure was reported after four years service. 2) A welded steel heating coil (reference 63, Table I) carrying 150 psi steam in 50% caustic developed cracks in the bends of the coil after two years. The design was changed to produce a better support of the coil and the welds were stress relieved.

Many contributors noted in this questionnaire that stress relieving treatments had been applied after welding fabrication. The consensus was that stress relieving is beneficial and consequently in some cases stress relieving was made mandatory. The above remarks applied in the main to vessels which could be furnace stress relieved. A few cases were cited in which local stress relieving was done but no details were given of the method used.

There is a divergence of opinion on the use of welding for the repair of cracks. Several contributors reported that cracked equipment could not be repaired satisfactorily by welding whereas others reported that welded repairs were made with some degree of success. There is a good possibility that repairs can be made by welding if an adequate method of stress relieving can be devised.

Several contributors stated that riveted tanks were superior to welded tanks in caustic service. This observation may be due to the different stress patterns in a riveted tank.

Factors Affecting a Decrease in Temperature

It is possible in some cases to decrease the metal temperature of a unit by a change in its design. A reduction in temperature was accomplished by a change in design as cited in the following two cases: 1) A steel measuring tank (reference 57, Table I) containing 50% caustic at 100° F was heated externally at the bottom of the tank by means of a coil at 300° F. Cracks developed in the tank in one year. The cracked section was replaced and the coil was lowered about one and one-half inches to decrease the temperature on the bottom of the tank. No further difficulty was experienced. 2) A welded steel storage tank (reference 59, Table I) containing 50% caustic at 150° F was heated by means of a two inch coil inserted through a welding neck in the side of the tank near the bottom. The coil was heated by steam at 150 psi. Convection currents could not remove heat from the welding neck rapidly enough and high temperatures resulted in the caustic in this area. The welds in the neck cracked in six months. The design of the welding neck was therefore changed so that convection currents could carry away the heat.

Changes in operating conditions can sometimes also be achieved to affect a decrease in temperature as illustrated by the following three examples. 1) A

welded rectangular steel storage tank (reference 60, Table I) was used successfully to handle 50% caustic at 120° F for three years. A change in process required the dilution of 72% caustic to 50%. The temperature was raised to 230° F by the dilution and the tank failed in three days. After a nickel caustic cooler was installed to lower the temperature in the tank to 120° F no further trouble was encountered with cracking. 2) A welded steel tank (reference 79, Table I) was used for storage of 50% caustic after dilution from 72%. The dilution was made about once a month and the temperature occasionally reached 220° F. The tank failed after some six months of service. The process was changed by diluting the caustic to 25% and after nine years the tank is still in service. 3) Pipe lines carrying caustic (reference 72, Table I) are sometimes steam traced. In this instance the lines were carrying 50% caustic and the steam tracing was supplied with 150 psi steam. Failure of the pipe was noted but by decreasing the steam pressure on the tracing line to 30 psi the life of the caustic line was increased.

Factors Affecting A Change in Materials

It seemed to be the consensus that to eliminate stress corrosion cracking in steel a change to nickel or Monel Metal or nickel clad steel was indicated. The actual selection from the three metals will be determined by the economics involved. It was also apparent that the limiting conditions under which steel may be used safely has to be clarified.

Several contributors reported cracking of nickel welds in nickel clad steel plate. A nickel clad steel tank (reference 66, Table I) used in 50% caustic at 176° F failed in the nickel clad welds after ten years service. The failure was repaired by welding a nickel butt strap over the nickel weld. A nickel clad steel storage tank (reference 81, Table I) containing 70% caustic at 180° F failed in the welds after six months service. Improved welding and inspection techniques were subsequently developed to insure sound joints on the nickel side. A salt separating tank (reference 31, Table I) constructed of welded nickel clad steel failed adjacent to the welds after eight years in 10-25% caustic service at 160° F. The metal was judged as embrittled when chipping and welding were unsuccessful. However, welding butt straps over the nickel welds as well as spraying nickel over the weld area were both found to be successful in repairing the failures.

The first two cases cited above seemed to indicate that defects in the nickel weld such as porosity, incomplete fusion, slag, etc., were the probable cause of failure. The third case, however, seemed to indicate stress corrosion cracking. Additional information may clarify this point.

Metal spraying the welded surface with nickel or steel was reported as successful. The use of caustic resistant coatings was also reported as successful but details of the types of coatings used were not given.

TABLE III—Contributors

Aluminum Company of America
American Cyanamid Company
Calco Chemical Division
American Finishing Company
Atlantic Refining Company
Buckeye Cotton Company
Chemical Pulp Division
Carbide and Carbon Chemicals Corporation
Cities Service Refinery
Corn Products Refining Company
Dow Chemical Company
E. I. duPont de Nemours & Co., Inc.
Grasselli Chemical Works
Esso Standard Oil Company
Louisiana Division
Ethyl Corporation
Hercules Powder Company
International Nickel Company
Lever Brothers Company
Lindsay Light and Chemical Company
Mathieson Chemical Corporation
Lake Charles Operations
Monsanto Chemical Company
Nopco Chemical Company
Phillips Petroleum Company
Pittsburgh Plate Glass Company
Columbia Chemical Division
Potash Company of America
Procter and Gamble Company
Rohm and Haas
Southern Alkali Corporation
The Standard Oil Company (Ohio)
Union Oil Company of California
Los Angeles Refinery

Alkaline Solutions Other Than Caustic

The data in Table II concern stress corrosion cracking of mild steel, stainless steel and brass, exposed to alkaline corrosives other than caustic. The corrective measures recommended were much the same as those previously discussed.

Summary

To prevent stress corrosion cracking in alkaline solutions, the recommendations that were made, based upon actual plant practice, may be summarized as follows:

A. Decrease stress (residual and applied)
   1. Change design
   2. Stress relieve
B. Decrease temperature
   1. Changed design
   2. Change operating conditions
C. Change material of construction
   1. Different metal
      a. Nickel
      b. Monel Metal
      c. Nickel clad steel
   2. Coatings
      a. Spraying with nickel
      b. Spraying with steel
      c. Organic coatings

Future Considerations

The study of the reported plant experiences raised a number of questions, answers to which would be profitable. The following are some points that might be investigated further.

1. Different methods of stress relieving and their effectiveness in eliminating cracking. This would include methods for field erected tanks and repair welding.
2. Effectiveness of shot peening as stress reliever.
3. Influence of cathodic protection on cracking.
4. Use of coatings.
5. Analysis of steels with regard to impurities as a function of cracking.

This committee requires further information on either good or poor performance of materials in caustic service, with particular reference to steel. It will be appreciated if anyone having such data will contact any member of the committee.

Acknowledgments

The committee wishes to express its gratitude to the many individuals who spent time in preparing the questionnaires and to the many companies for release of the information. The list of contributors is given in Table III. Acknowledgment is also given to McGraw Hill Publishing Company for permission to publish the data given in Figure 6 which was taken from "Chemical Engineering."

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Corrosion Problems of Motor Coaches*

By K. L. RAYMOND

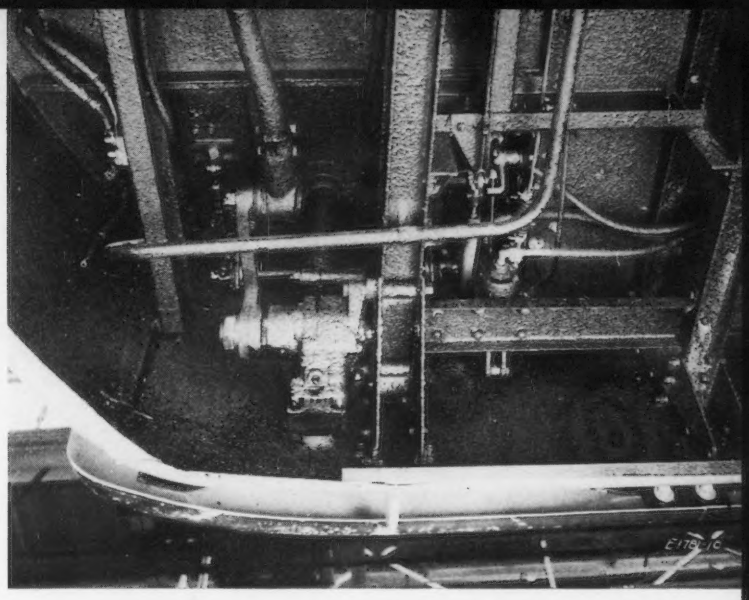

Figure 3—Tough asphalt coating on underside of motor coach.

K. L. RAYMOND—Responsible for engineering work on painting, plating, corrosion, miscellaneous materials, rubber and plastics with General Motors Truck and Coach Division, Pontiac, Mich., he became associated with the division while attending GM Tech in 1930. He has held positions in inspection, and engineering departments. A graduate of General Motors Institute, he has done post-graduate work at Lawrence Institute and Wayne University. He is a member of American Electroplater's Society.

Abstract

Motor coaches must provide safe and dependable transportation. Quite a variety of corrosion problems present themselves in the construction and operation of motor coaches. Some of those which concern the body are: electrolytic or galvanic corrosion between the aluminum and steel of body and frame; water vapor condensation due to respiration by passengers; abrasion and corrosion of understructure by stones and other debris thrown up by the tires, including chlorides used on the roads for de-icing and dust control; acid attack by battery electrolyte; wear and attack on stanchions, grab rails and other assist handles due to perspiration, rough hands and fabrics. Coach engines have their share of corrosion problems, too, particularly in the cooling and exhaust systems. Although numerous corrosion inhibitors do a reasonably fair job in the cooling system. Exhaust systems suffer from cold corrosion due to acid from condensation of products of combustion of the engine. However, high temperature oxidation is usually a more serious problem than cold or acid corrosion in motor coach engine exhaust systems. On some heavy duty operations the exhaust pipe runs as high as 1600° F for many hours at a time.

THE RESPONSIBILITY of keeping corrosion problems under control is nowhere more important than in motor coach construction. Each vehicle represents a considerable capital investment and must show a good life span as a return on that investment. Some inter-urban coaches average as much as 400 to 500 miles per day which is 12,000 to 15,000 miles every month and they must keep going month after month. The present goal is to build coaches capable of withstanding the rigors of such demanding service in all kinds of weather for 10 years or more.

As a matter of fact some coaches on the road during the last war were over 10 years old and several had traveled as much as 2 million miles. From a corrosion standpoint these coaches were structurally sound and presented a good appearance. Possibly this was a result of the naturally good corrosion resistance of aluminum which was the chief metal of construction. At any rate it was a sharp contrast to the appearance of many pleasure cars at the close of the war.

The corrosion problems in motor coach construction are probably similar to those of other industries. Sometimes the choice between economy and ultimate protection is a delicate decision requiring careful study of all factors involved. Examples cited will show some of the corrosion problems and demonstrate the principles used in protecting motor coaches.

Condensation is responsible for most motor coach corrosion. Everyone is familiar with the rapid formation of "fog" on car windows in cold weather. This is water of condensation caused by the breathing, or more truly the respiration, of the 2 or 3 persons generally riding in the car.

The average human gives off ¼ to ⅓ pound of water in the form of water vapor every hour.[1] Visualize the immense volume of condensation formed inside a 45 passenger coach particularly when it is occupied by 75 persons on a cold December morning. Two to three gallons of water must be accommodated, controlled and disposed of every hour.

This condensation provides an ideal electrolyte for galvanic corrosion where dissimilar metal couples exist and might be poorly protected. In addition the

* A paper presented at the Seventh Annual Conference and Exhibition, National Association of Corrosion Engineers, New York, N. Y., March 13-16, 1951.

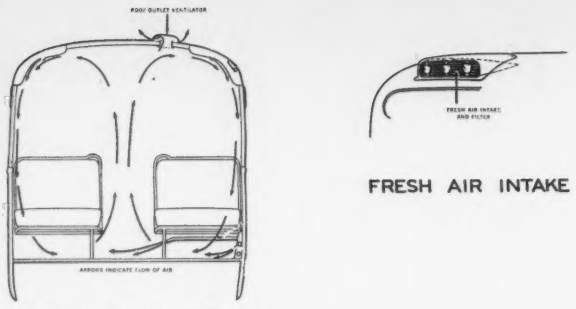

Figure 1—Air circulation of typical transit coach.

moisture itself reacts with various materials causing considerable deterioration. Iron rusts, paints soften and blister, chemicals leach out from some materials and cause corrosive attack on other items all because of this unwelcome presence of water. Such condensation is best controlled by proper heat and ventilation. Figure 1 shows how this is accomplished in a typical transit type coach. Fresh air enters the intake above the destination sign at the front. It is forced through a heater core by blowers and along passages behind the card rack panels on either side of the roof. The warmed air escapes through a row of outlets in such fashion to cause a downward wiping action across the passenger windows, thus preventing formation of fog on these surfaces.

The wiping action of the heated fresh air warms the inside surface of the windows preventing condensation at these points, and being warmed, has the capacity to absorb the moisture developed inside the coach. The suspended water vapor is exhausted through the roof outlet ventilator.

Figure 2 shows a side section of the body which is composite construction of ferrous and non-ferrous materials and poses numerous problems of possible electrolytic corrosion. Most body and roof panels are 52-S aluminum alloy. The body posts shown in Figure 2 are steel. It is general policy to treat all detail parts before assembly with a phosphate metal conditioner and to apply a coat of primer to all surfaces. In this way all surfaces have at least one coat of protective material particularly at the lap joints.

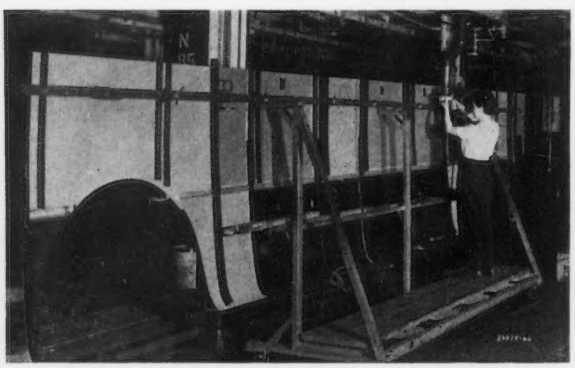

Figure 2—Side section of coach under construction.

The phosphate used is Bonderite #170. This produces an effective phosphate treatment on aluminum and steel thereby simplifying manufacturing operations by permitting a single processing unit in place of separate selective units for aluminum and steel. Zinc chromate primer is used on aluminum and an iron oxide primer on steel sheet parts. The inner surfaces of all body panels also receive a coat of synthetic enamel before assembly. Parts which lend themselves to dipping such as the steel side posts are coated with a high bake oleo-resinous black primer. In addition a plastic caulking compound containing chromate inhibitors is used on the faying surface between dissimilar metals wherever the possibility of corrosion prevails.

After the coach body has been completely assembled, the usual surfacer and color coats are applied for exterior finish. Synthetic enamels are used for this purpose. Where it is necessary to use plated coatings, such as on bolts, nuts, washers, etc., zinc or cadmium plate is preferred. Stainless steel also is satisfactory in contact with aluminum but metallic copper and lead coatings tend to aggravate corrosion and are avoided.

Figure 3 shows the underside at the front end of a motor coach. These understructure areas are subjected to severe abrasion. Stones and dirt thrown up by the tires virtually sand blast the bottoms of these vehicles. The entire underbody is coated with a tough asphalt type undercoater as shown here. This material is resistant to abrasion and is an inert protective film as well. In addition rubber fender flaps are mounted directly behind each wheel in direct line with the blast from the tires. These flaps absorb the most severe part of the blasting and divert many objects out from under the coach.

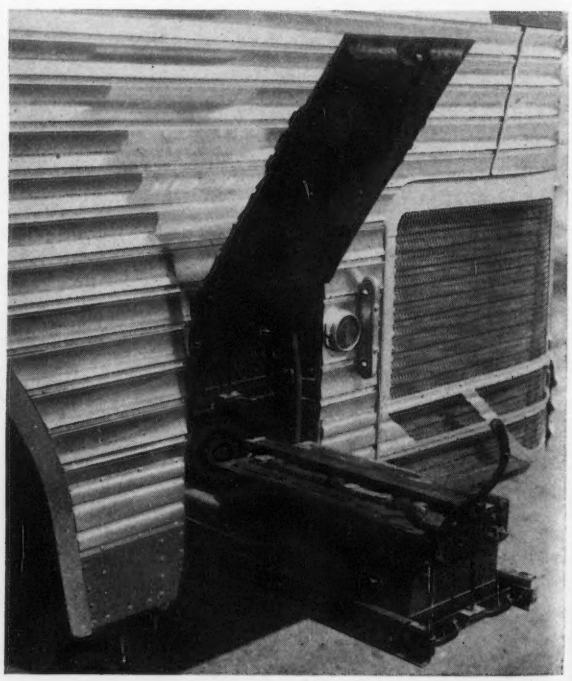

Figure 4—Aluminum battery carriers and supports.

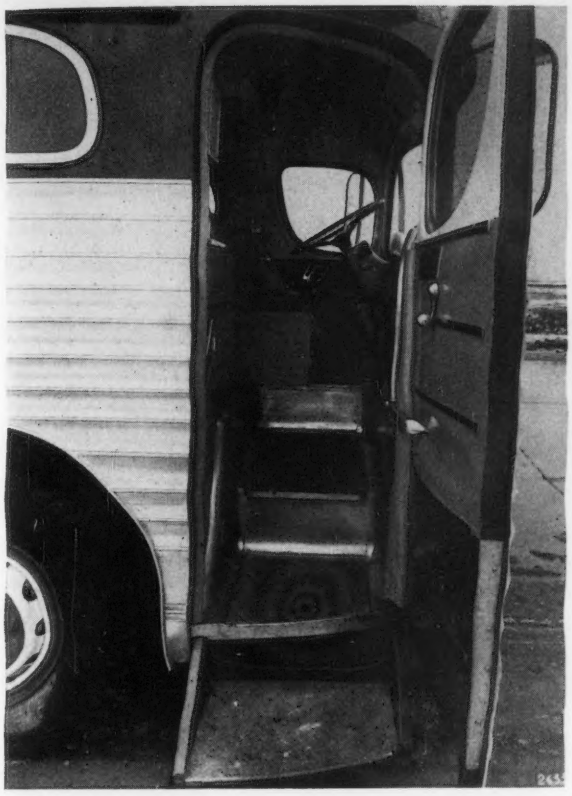

Figure 5—Generous coves in stainless steel stepwell.

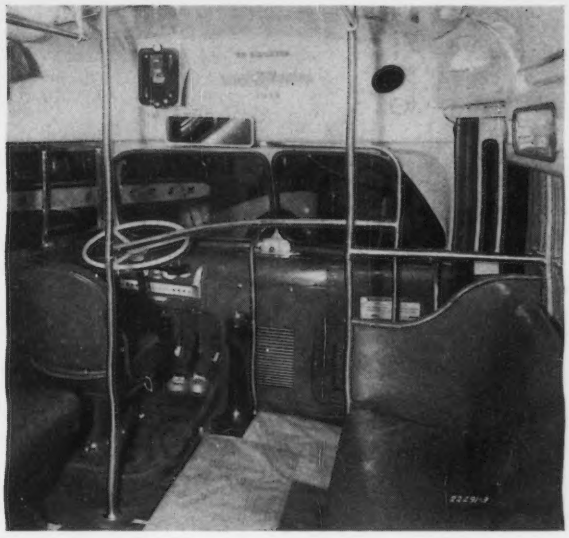

Figure 6—Stainless clad steel grabrails and stanchions.

Chlorides used on roads for de-icing or dust control cause severe attack on unprotected metals. In addition to protective treatments and coatings previously mentioned for the understructure parts, every attempt is made to avoid pockets or shelves where dirt and moisture might be trapped. A well drained and clean understructure is the easiest to keep free from corrosion.

Areas immediately adjacent to the storage battery have always suffered attack by sulphuric acid. Hot dip lead coatings provide a measure of protection for steel and acid-proof asphaltums generously applied have also helped. Figure 4 shows battery carriers and supports now made of aluminum. The natural resistance of this material to battery acid has proven highly satisfactory.

Coverings for floors and stepwells are designed, built and installed to resist as well as possible the abrasive and corrosive materials brought into the coach on customers' feet. The most severe part of this action is at the entrance door. (Figure 5.) Here durability and safety have been obtained by use of

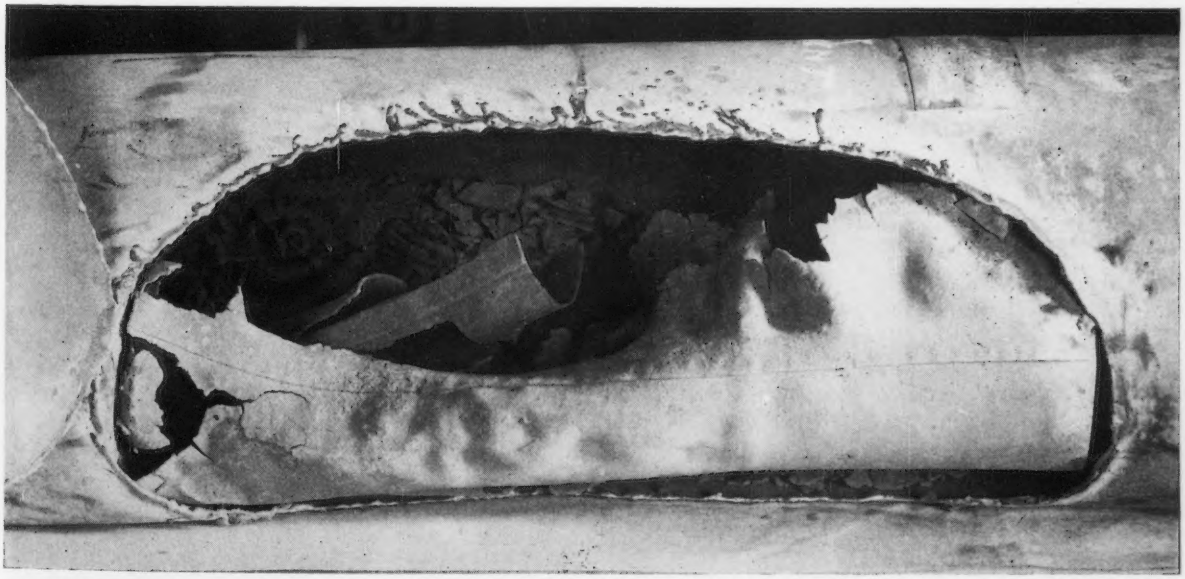

Figure 7—Typical high temperature "burning" of muffler of heavy duty gasoline engine.

carborundum abrasive imbedded in cast aluminum tread plates. Generous coves designed into each corner of the 18-8 type stainless steel step-well also aid in preventing dirt and slush accumulating at these points with their resultant corrosive action. These coves also aid in easy and complete cleaning of the stepwells.

Grab rails, stanchions, and other assist handles shown in Figure 6 receive concentrated heavy duty wear aggravated by perspiration and abrasion from rough hands, fabrics, etc. The use of a 12% straight chromium stainless clad steel has proven far superior to bright electroplated coatings for these applications by giving longer wear life and better continuous appearance.

Mufflers of heavy duty gasoline engines sometimes operate at temperatures as high as 1550-1600° F. Figure 7 is a muffler from such an engine showing typical high temperature oxidation or "burning" which sometimes occurs under these conditions. Inconel (78% nickel-14% chromium) has very good resistance to this type attack. Aluminum coated steel and vitreous enamel coatings have also proven quite satisfactory on these high heat applications.

About 95% of the GMC coaches sold today are diesel powered. (Figure 8.) The mufflers on these engines do not suffer high temperature corrosion because their exhaust temperatures do not exceed 800° F which is well below oxidation temperatures of materials commonly used for these parts.

Engine cooling systems present many corrosion problems (Figure 9). This corrosion has been, and is, the object of several extensive projects. ASTM Committee D-15, the National Bureau of Standards,[2] the Aluminum Company of America and doubtless many others have conducted investigations in this field. Several technical papers have been published on this subject alone. "Problems of Automotive Cooling System Corrosion Inhibition" by Green and Willihnganz[3] is a very thorough and complete presentation of this problem.

Time will not permit enlarging in detail all the corrosive conditions in engine cooling systems. However, a brief summary might serve to show the complexity of this problem where practically every type of corrosive condition is present. There is galvanic corrosion or electrolytic couples such as between aluminum and cast iron and between copper and aluminum; concentration cell corrosion in pockets where water is trapped; erosion due to velocity of fluid flow and abrasive action of entrained solids; cavitation such as experienced in many fluid pumps; alkali attack due to high alkali content of some natural waters used in these cooling systems and acid attack due to products of combustion leaking into water system or to breakdown of certain types of anti-freezes. In addition there are probably other types of corrosion attack present under some peculiar conditions.

The effects of any one of these corrosive conditions can generally be understood and controlled. When combined in one system and aggravated by vibration and aeration as in automotive engines, the problems become very complex.

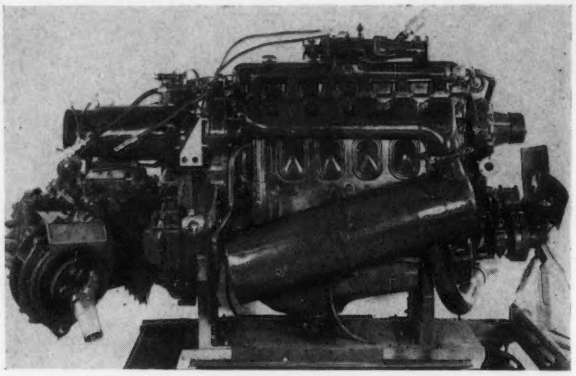

Figure 8—Diesel engine used in many of the motor coaches now made by the author's company.

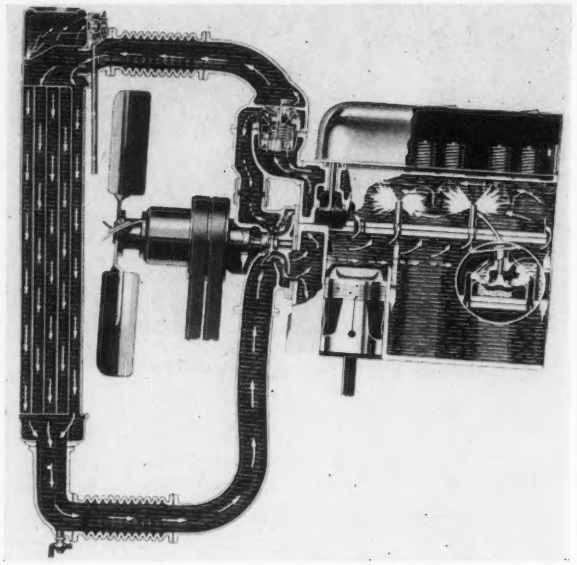

Figure 9—Engine cooling system.

Cooling system corrosion is for the most part quite well controlled by the use of inhibitors. Most anti-freeze compounds contain corrosion inhibitors for this purpose. When anti-freeze solutions are not used, a small addition of soluble oil seems to be the most acceptable corrosion inhibitor. Soluble oil coats the inner surfaces of the cooling system with an oily film. This film protects these surfaces against corrosion but reduces the cooling efficiency. There remains an opportunity for much improvement in the control of cooling system corrosion.

Occasionally complaints arise which involve corrosion and which must be analyzed to determine cause and correction. An illustrative case is presented.

In February, 1944, coaches in intercity service in Detroit began to show roof panel failure. It was reported that four out of ten coaches examined were affected. Further investigation proved this failure less extensive than first indicated but the problem

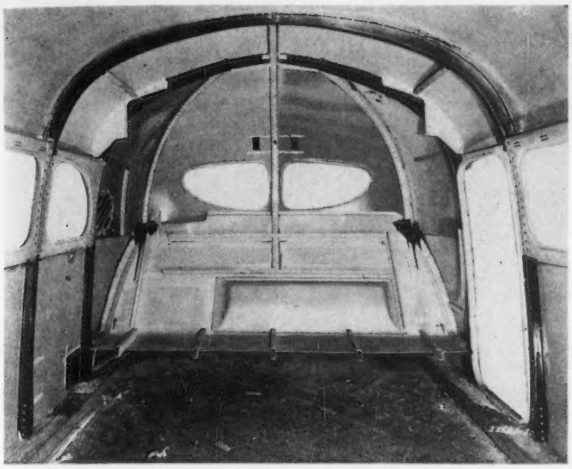

Figure 10—Interior of motor coach under construction.

was serious and could be eliminated. Figure 10 shows the interior of this particular model coach while under construction. The most severe corrosion was concentrated in a line about 8 inches above the top of the window which coincided with the lower edge of roof insulation pad.

The ultimate explanation of the failure was found in a study of the binder used on glass wool insulation which is installed in the roof sections. Specifications require that each insulation batt be wrapped in Kraft paper for ease in handling and to protect workers against the glass. One batch of batts was received without the paper wrapper. These had been spray coated with a latex compound as a binder in place of the paper. This latex was coagulated, probably with ammonium hydroxide or some other alkali, and then the coagulation "set" with hydrochloric acid. This left a water soluble salt, such as ammonium chloride, deposited on the surface. The salt was then dissolved by moisture of condensation and over a period of time formed a high concentration along the bottom edge of the insulation batt by natural drainage and evaporation. The strong chlorides in solution then attacked the aluminum.

The unwrapped batts were removed from the few coaches affected, the corroded spots repaired, and the batts wrapped and reinstalled. No further trouble has been reported from this source.

Conclusion

It is apparent that these corrosion problems are not unique or peculiar to this industry. The exposure is not particularly severe as compared with the handling of brine or strong acids, etc. Probably the biggest problem is the variety of corrosive conditions which must be controlled.

There is no reliable accelerated corrosion test or combination of tests which can give quick answers to these corrosion problems. Therefore the builder has had to be guided mainly by field results, or actual performance in the hands of customers, for ultimate answers. This is an undesirable method of operation, but with the good cooperation of many customers the problems have been worked out and certain principles have been established as guides in designing and engineering new coaches.

A 10-year coach presents no special problem so far as protecting it from corrosion is concerned.

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2. D. B. Brooks and R. E. Streets. "Automotive Antifreezes," Nat. Bur. Standards Circular 474.
3. Green and Willihuganz. "Problems of Automotive Cooling System Corrosion Inhibition," National Carbon Company.

DISCUSSION

Question by Raymond A. Shoan, Dearborn Chemical Co., Chicago, Ill.:

What inhibitors are involved in the cooling system?

Author's Reply:

In presenting the paper wholly from slides comments concerning use of inhibitors in cooling systems was unintentionally omitted. Complete discussion appears in the written paper.

Questions by O. E. Kirchner, American Airlines, Tulsa, Okla.:

1. What is average life of bus?
2. Comment on cooling systems: I was interested to learn what their experience had been with corrosion in cooling liquid systems resulting from various types of hardness. It was interesting to learn bus people have under test means of softening water used for engine cooling systems. This was a severe problem for airlines at one time when steam was commonly used for aircraft heating and ventilation. Installation of special water treatment equipment at various stops was found necessary. Now that steam heating no longer is being used this is no longer a problem. Further information on this topic is available in the paper by myself and F. M. Morris presented at the 1950 NACE meeting in St. Louis and published in *Corrosion*, 7, No. 5, 161-177 (1951) May.

Author's Reply:

1. Generally our customers plan to operate our buses about 10 years before replacement. After that the buses are either sold or placed on minor operations. It would be very difficult to establish a more accurate estimate of average bus life.

2. In connection with combating water hardness a type of water filter containing zeolite has recently been promoted for automotive cooling systems. In addition to zeolite these filters contain a chromate and some magnesium "resistor plates" which aid in combating corrosion of metal parts. Reports of several operators using this equipment are very favorable and laboratory tests indicate these devices have good possibilities. Such equipment may be obtained from Spark-O-Liner Corp. (Perry Filter), Minneapolis, Minn. and from Fram Corp., Providence, Rhode Island. There may also be other sources.

Corrosion Problems In Rural Power Distribution*

By ORVILLE W. ZASTROW*

Abstract

Large scale construction of rural electric distribution lines in almost all parts of the United States has given rise to a variety of corrosion problems. Some are the result of special local conditions, while others are related to changes that came about when lines were designed for rural rather than urban construction. The corrosion problems are complicated by a wide range of atmospheric and soil conditions and by the difficulty of observing some kinds of damage before failure occurs.

On multigrounded wye distribution lines all underground metal parts are generally connected to a common system neutral conductor in order to maintain the lowest ground resistance possible. Underground corrosion has been excessive in some locations because of galvanic action between metal surfaces that assume varying potentials with respect to the soil.

Atmospheric corrosion problems in pole line hardware are characterized by replacement costs that are very high compared with the value of the items replaced and by questions of choice of materials and coatings for a wide range of atmospheric conditions. High strength primary conductors, widely used in rural construction, depend on steel for strength while aluminum or copper provide electrical conductivity. These composite conductors have performed well in most atmospheres but corrode excessively under certain conditions.

Durability of transformer paints is being examined with the object of increasing the useful life of the coatings, as transformers represent a large item in the cost of a distribution system. The cost of maintenance painting of distribution transformers is so high that the economy of repainting small transformers is questionable unless they have been removed from service for other reasons.

RURAL POWER distribution lines are neither impressive in appearance nor very costly in dollars per unit of construction compared with transmission lines, generating plants, or other equipment for handling large blocks of power. As a result they often do not receive such careful engineering study in design or in regard to well-planned maintenance as do the generating or transmission plant. However, the distribution plant is likely to represent a greater investment than either generation or transmission plant where all energy generated is being distributed. Maintenance costs per dollar of plant investment are inevitably high on rural distribution lines because of problems of distance and of maintaining service while maintenance work is done. Careful design, with regard for maintenance costs, is important under such circumstances.

Corrosion on rural distribution systems is characterized by comparatively simple reactions damaging relatively inexpensive items of equipment on such a wide scale that something must be done about it. The damage occurs under such a variety of conditions that general mitigative measures often are not the answer. Also, the operator of a distribution system is not in a good position to effectively deal with corrosion problems because of the specialized knowledge required and the high cost of learning by experience. Assistance to such operators is the object of corrosion studies now being conducted by engineers of the Rural Electrification Administration. This paper is a summary of some of the corrosion problems under study and the mitigative measures being applied or considered.

Underground Corrosion

Galvanic Corrosion

One underground problem at present is the galvanic corrosion of galvanized steel anchor rods that are electrically connected to copper grounding electrodes.

REA-type distribution lines have a multigrounded neutral conductor. Ground electrodes connected to the neutral include driven copper-covered rods and pole butt grounds consisting of plates of coiled copper wire. In most cases steel guys, which are electrically bonded to the anchor rods, are connected to the system neutral. Bonding guys to the system neutral is desirable for electrical reasons, but in some areas accelerated corrosion of anchor rods has resulted. Where the corrosion is serious, strain insulators are being installed in guys to isolate the anchor rods from the system neutral.

A study is being made to determine the conditions under which guys may be connected to the system neutral without excessive corrosion and to determine where strain insulators must be used to prevent corrosion. The rate of corrosion of anchor rods in service is being checked by measuring galvanic currents and by making spot checks on the physical condition of anchor rods. Equipment has been constructed for measuring galvanic currents by a zero resistance milliammeter method, using the circuit shown in Figure 1. The input terminals are connected to the guy and to the system neutral by using a 50-foot lead, and current values are read from M_1 with the circuits adjusted so that M_2 reads zero. The equipment is designed to operate satisfactorily with 100 volts rms at 60 cycles impressed across the terminals for the 0 to 5 ma and 0 to 25 ma ranges. Ranges of 0 to 125 and 0 to 300 ma also are available, with an external battery and milliammeter for the highest range.

* A paper presented at the Seventh Annual Conference, National Association of Corrosion Engineers, New York, N. Y., March 13-16, 1951.
* Engineer in the Technical Standards Division of the Rural Electrification Administration, U. S. Department of Agriculture.

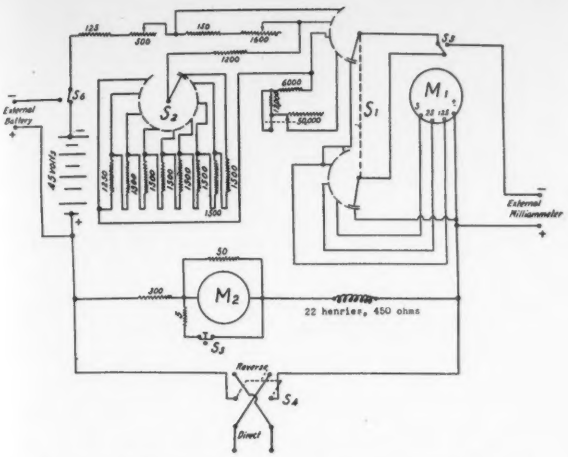

Figure 1—Circuit diagram for experimental zero-resistance milliammeter.

Direct current flowing from the system neutral to an anchor rod is used as an indication of the rate of corrosion of the anchor rod. This assumes that the most important corrosion is associated with the measured current and not with local action between parts of the anchor rod. Based upon Faraday's law relating galvanic corrosion to galvanic current, for an electrochemical equivalent of 2.8938 x 10^{-4} grams per coulomb for $Fe = Fe^{++} + 2e^{-}$, the rate of metal removal is approximately one pound for each 50 milliampere-years of current flow.[1] For an anode reaction in which the iron has a valence of 3, this becomes one pound for each 75 milliampere-years.

A ⅝-inch steel anchor rod has a weight of two pounds per foot, or approximately 15 pounds for the buried portion of an 8-foot rod. It is felt that such a rod usually would not be seriously weakened by a loss of ½ pound of metal but that serious weakening may be expected from a loss of three pounds or more of metal. On this basis, it appears that currents of less than 0.5 milliampere are not particularly serious and that currents of 5 milliamperes or more cannot be permitted. Additional field data may permit more specific conclusions and result in revisions of the 0.5 milliampere and 5 milliampere figures.

Measurements made on lines of a distribution system in southern Virginia in January 1951, indicated galvanic currents in the range of 1 milliampere to less than 0.1 milliampere, the only exception being a single measurement of 2.4 milliamperes for a guy and anchor in swampy clay soil. From these measurements, and from visual examination of anchor rods removed after 4 to 14 years of service, it appears that corrosion is not likely to be serious on lines of that particular system, with anchor rods bonded to the system neutral. Ground resistances are relatively high so that the anchors are helpful as additional grounds.

On lines of two rural systems in Southern Texas galvanic action has caused anchor rods to fail after less than four years of service in some locations. The damage is occurring mainly in the basic alluvial soils that provide the most fertile farm land in that area. Under very dry surface conditions (February, 1951), direct currents of 11 milliamperes were measured at two locations where anchor rods had failed and been replaced after four years of service. Five milliamperes dc were measured where an anchor rod had failed after nine years service. In other areas served by the same system, the direct currents were negligible in the clay-like soils known as caliche.

Underground corrosion has caused damage to anchor rods in some alkaline or ore-bearing soils of other Midwestern states, but the galvanic currents involved have not been measured at the time of this writing.

Electrolysis

Direct currents from cathodic protection systems for pipe lines are likely to find their way onto the neutral conductor of a multigrounded distribution line, with resulting damage to anchor rods and other underground electrodes where the currents return to earth from the metallic circuit. This presents a difficult problem in southern Texas where lines of a distribution system may cross many different pipe lines. The buried anode for a rectifier installation is often installed along the same right-of-way as the distribution line serving the rectifier. Measurements in the vicinity of one rectifier installation indicated a total of more than 4.5 amperes of direct current flowing into the system neutral. At other installations currents of 0.1 ampere or more per grounding electrode were measured flowing into the neutral near the rectifiers. These measurements were made on the lines of the San Patricio Electric Cooperative, Sinton, Texas.

A convenient return path for electrolysis currents could be provided by a bonding connection between the neutral and the protected pipe line, if an arrangement is possible that will not cause damage to other pipe lines and if such a bond is acceptable to the pipe line agency.

For the present, distribution cooperatives are being advised to make connections to ground only through gaps, within 1000 feet of rectifier installations. As an additional precaution, all guys in the area are being isolated from the neutral to prevent failures of anchor rods. Grounding electrodes will be supplemented by larger steel ground rods wherever effects of corrosion are noted.

Atmospheric Corrosion

Hardware, General

The importance of hardware corrosion on distribution pole lines is easily underestimated because of the relatively small cost of the individual parts involved. When the cost of replacing hardware is considered it becomes evident that the use of parts with a life shorter than that of the wooden structures is, in general, a costly mistake. The usual practice in rural power distribution throughout the United States has been to use mild steel hardware that is hot dip galvanized in accordance with American Society for Testing Materials Specification A 153-49.[2] The specification provides for a minimum average weight of zinc coating for any one specimen of 1.00 to 1.80

ounces per square foot of surface, depending on the class of material and dimensions of the part.

The most extensive data on atmospheric corrosion of zinc-coated steel are provided by the American Society for Testing Materials from tests that have been under way since 1925.[3] These test data indicate that the zinc coatings provided by hot dip galvanizing should generally be satisfactory for rural atmospheres.

The majority of rural distribution lines are located in atmospheres that should be similar to those referred to as "rural" in connection with the ASTM tests. However, some lines are located where conditions favor relatively severe atmospheric corrosion and in some of these cases the hot dip galvanized mild steel hardware does not have adequate resistance to corrosion. The problem of choosing materials or coatings for such conditions has been difficult because of insufficient data on performance of other types of hardware in similar circumstances and insufficient knowledge of the corrosion reactions causing the trouble.

The low alloy steels, stainless steels and bronze alloys all have advantages to offer as materials for hardware. However, the advantages of increased strength and corrosion resistance must be weighed against higher costs of material and fabrication, keeping in mind that the useful life of the hardware should be coordinated with that of the structures on which it is used.

Insulator Pins

In some coastal areas of Texas, steel pole top pins have been penetrated or have rusted off completely in less than 10 years. These pins are made of 9-gauge (about 0.15 in.) steel, coated with approximately 1.5 ounces of zinc per square foot of surface. A threaded "cob" made of lead is cast or otherwise applied around the end of the pin, to prevent excessive stresses in the threaded porcelain insulator.

Corrosion of the insulator pins is concentrated in the area within one or two inches of the lead "cob," where the insulator skirt shields the pin from rain and also retards drying when the pin is moist. Figures 2 and 3 show a pole-top pin and a crossarm pin that have corroded under such conditions. In each case, the corrosion seems to be most rapid near the lead "cob." Factors that aggravate corrosion include high humidity, contamination by dust and possibly contamination by fumes from chemical plants or the sulfur dusting powders applied to cotton. Contamination of insulators and electrical leakage are serious enough to cause frequent burning of poles.

The most rapid damage to insulator pins seems to be associated with electrical leakage over the insulators. The leakage results in intermittent arcing or corona between the insulator skirts and the pin. The resulting damage to the pin is characterized by formation of a rust blister that may approach ¼-inch in thickness.

Figure 3—Crossarm pin after approximately ten years of service on lines of the Nueces Electric Cooperative, Inc., Robstown, Texas.

The nature of the corrosion on some insulator pins suggests the possibility of galvanic action between the lead "cob" and the zinc-coated steel surfaces, with anodic reaction at the zinc-coated steel electrode.

Damage due to leakage currents can be reduced by increasing the insulation of the line to reduce the amount of electrical leakage. This is being done in some of the Texas areas referred to. Other measures under consideration are use of pins with larger cross section, use of arcing electrodes and protective coatings.

The value of alloy steels for insulator pins seems doubtful in the case referred to on the basis of information on hand. Additional information on the corrosion reactions involved is needed before further conclusions can be reached.

Conductor

High strength composite conductors of copper and steel or aluminum and steel are widely used in rural distribution lines. Where corrosion is a problem, the high strength conductors are more vulnerable than solid copper conductors, because corrosion of the steel that provides strength in a conductor will result in conductor failure in almost all cases.

A commonly used type of copper-steel composite conductor is made with various combinations of steel-cored copper strands and solid copper strands twisted together. ACSR (aluminum conductor, steel reinforced) is made with aluminum strands surrounding a core of one or more galvanized steel strands. While both of these types of conductor have exhibited good corrosion resistance under a wide variety of conditions, there are locations where each may not provide satisfactory corrosion resistance.

Any damage to a copper covered steel strand that

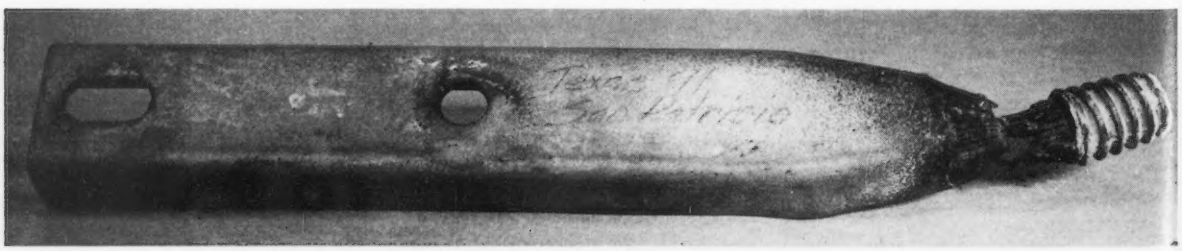

Figure 2—Pole-top pin after approximately ten years of service on lines of the San Patricio Electric Cooperative, Inc., Sinton, Texas.

causes the steel to be exposed generally leads to rapid corrosion of the steel core and a conductor failure. Where a conductor has failed in service, initial penetration of the copper has usually been attributed to damage during stringing or manufacture. In a few cases, corrosion of the copper itself has resulted in failures of the composite conductor so that replacement of the conductor becomes necessary.

Measures being used or considered for reducing conductor damage due to corrosion include the following:

1. Increased use of protective armor rod at points of support and where electrical connections are made for copper and copper-steel types of conductors.
2. Increased use of conductor performance data for determining areas or conditions under which certain kinds of conductors may or may not be used. These data may also be useful in determining optimum tensions for conductors.
3. Providing special corrosion protection by means of polyethylene or other coatings over conductors, for extreme cases.

Where lines have been built for the high-strength composite conductors, the original conductors generally cannot be replaced with hard-drawn copper unless the lines are re-staked and poles added. There is a need for new conductors with sag characteristics similar to those of the present high-strength conductors but with increased corrosion resistance, for use in cases where corrosion problems are experienced on existing lines.

Coatings for Distribution Transformer Tanks

If rural distribution transformers are taken out of service for maintenance painting, the total cost including labor and transportation is so high that the value of the smaller transformers often does not justify such maintenance. That being the case, the maximum life of a transformer may be determined by the corrosion-resistant properties of the original coating and tank, unless painting is done when the transformer is taken down for other reasons.

Some tanks for oil circuit reclosers and capacitors are being made of stainless steel or galvanized mild steel, although these metallic surfaces are considered less efficient in radiating heat than the dark painted steel surfaces generally used on transformer tanks. Unless recent improvements in transformer paints provide greatly improved corrosion resistance, there still will be a demand for more resistant transformer tanks in coastal areas. A higher price for such transformers would be well justified in some areas.

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1. Uhlig, Herbert H. (ed), The Corrosion Handbook. New York: John Wiley & Sons, pp. 1133, 1158 (1948).
2. Standard Specifications for Zinc Coating (Hot-Dip) on Iron and Steel Hardware. ASTM designation A 153-49 American Society for Testing Materials, Philadelphia (1949).
3. Report of Committee A-5 on Corrosion of Iron and Steel. *Proc. ASTM,* **50,** (1950) or 1950 preprint.

DISCUSSION

By J. G. Stelzer, Consumers Power Co., Jackson, Mich.:

In my experience, the static discharge over a pin insulator to a steel pin to a wood arm by itself should cause no burning of the galvanizing on the pin. However, I wonder if there could be a possibility of ozone being generated by the static discharge. The ozone, in combination with the severe atmospheric conditions present, might be conductive to the degree of corrosion experienced.

The lead shields on the pins may be a factor in this corrosion, although I cannot see why. It would be easy to check on this by substituting a few pins of other design for observation of corrosion.

Author's Reply:

I believe that ozone or other ions produced in connection with the electrical discharge play an important part in the pole top pin corrosion referred to, although no information on specific reactions of this type seems to be available. Our observations in Texas to date agree with Mr. Stelzer's statement that the corrosion apparently is not due to heating or burning by the arc or to reactions involving the lead portion of the pin.

Prevention of Corrosion and Metal Attack in the Steam Water Cycle of the Steam Power Plant*

By FREDERICK G. STRAUB* and HARRY D. ONGMAN**

Abstract

This paper covers the potential sources of iron and copper solubility in the preboiler cycle and the effect of these metals on the steel in the boiler. The results of studies conducted to determine the effect of pH in the cycle on the solubility of these metals are given. These include the effect of increasing the pH of the steam and feed water by means of the controlled addition of ammonia to the cycle. It is shown that by maintaining a pH of 9 in the feed water by use of ammonia the copper as well as the iron solubility has has been reduced to very low values. Methods of adding and controlling the ammonia in the cycle are given. A discussion is given of the action of reducing chemicals in the boiler beyond their normal action on free oxygen. This covers the potential action of these reducing chemicals in reducing the iron and copper entering the boiler so that they will not come in contact with the boiler metal until they have been reduced and thus eliminate these metals as potential oxygen carriers.

METALS WHICH are picked up in the preboiler cycle of the steam power plant enter the boiler and, unless removed in the blowdown, accumulate in the boiler. The forms in which these metals enter the boiler and their distribution within the boiler may be the explanation of corrosion and metal attack which take place within the boiler.

In a central steam electric generating station with a closed cycle the steam and water come in contact with large areas of copper, copper alloys and steel. In steam power plants not having a condensing cycle the amount of copper and copper alloys in contact with the steam and water may be very small.

Laboratory Tests

Copper and iron are appreciably soluable in pure water even in the absence of oxygen. A series of tests were conducted at the University of Illinois in order to determine the solubility of these metals in a flowing stream of gas-free deaerated high quality distilled water.

Low carbon steel sawings were put in a steel tube through which water passed under pressure. The tube was heated to various temperatures and the water leaving the tube was cooled under pressure. The pressure was then released and the water passed through a closed conductivity cell and a flowing glass electrode chamber before exposure to the air. Figure 1 shows the pH and iron content of the water before and after passing through the iron. A second series of tests were conducted in which the water was passed through the steel sawings in a glass tube at room temperature. These results are also shown in Figure 1.

These tests indicate that distilled water containing oxygen and carbon dioxide which may be dissolved on contact with air will pick up iron but will not materially change the pH of water. When distilled water is deaerated to remove oxygen and carbon dioxide the pick up of iron is accompanied by an increase in pH. This pH reaches a value around 9.1. When sodium hydroxide is added to the distilled water to obtain a pH above 9.1 before passing the gas-free water through the iron there is a very marked decrease in the iron pick up. This same result is also shown even in presence of oxygen.

The process whereby the iron is dissolved or prevented from going into solution may be explained by the following reactions:

$$Fe + 2H_2O = Fe(OH)_2 + H_2 \quad (1$$

$$4Fe(OH)_2 + O_2 + 2H_2O = 4Fe(OH)_3 \quad (2$$

In the absence of oxygen the iron goes into solution as ferrous hydroxide with a resulting increase in pH caused by the increase in OH ions. When oxygen is present the ferrous iron is oxidized to the ferric form which has extremely low solubility and the pH is not changed. The finely divided ferric hydroxide is present in the water but not necessarily in actual solution.

When the pH of the original solution is 9 or above the presence of the OH ions tends to retard the iron

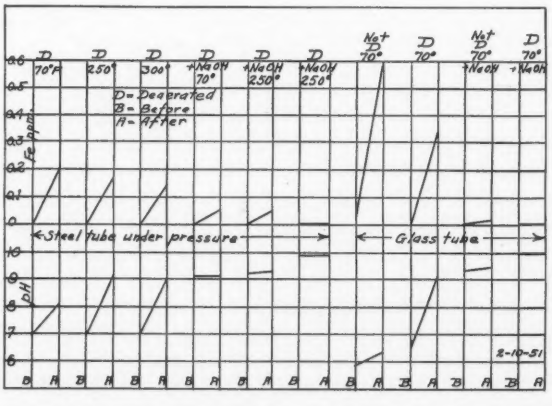

Figure 1—The pH and iron content of water before and after passing through steel sawings.

★ A paper presented at the Seventh Annual Conference and Exhibition, National Association of Corrosion Engineers, New York, N. Y., March 13-16, 1951.
The results reported in this paper were obtained as part of a cooperative program of the Utilities Research Commission of Chicago, Illinois and the Engineering Experiment Station, University of Illinois, Urbana, Illinois.

* Research professor, chemical engineering, University of Illinois, Urbana, Illinois.

** Research assistant, chemical engineering, University of Illinois, Urbana, Illinois.

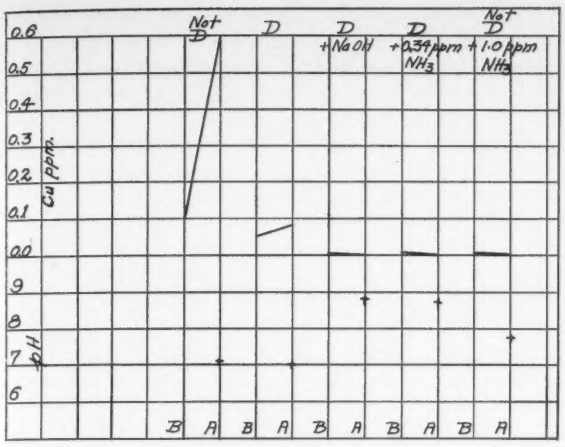

Figure 2—The pH and copper content of water before and after passing through copper sawings. Tests at room temperature. D—deaerated.

from going into solution and even in the presence of oxygen the ions have a retarding effect on the iron solubility or pick up.

A similar series of tests were conducted in which distilled water was passed through a copper pipe at room temperature to determine the copper pick up. (Figure 2.) A sample of undegassed distilled water passed through the copper tube showed a high pick up of copper with an end pH of about 7.0. The degassed water showed a much lower copper increase but also had an end pH of around 7.0. When sodium hydroxide was added to the degassed water so the pH was 8.8 there was no copper in the water leaving the tube. When ammonia was added to the degassed water (0.34 ppm) so the pH was 8.7 there was no copper pick up. When ammonia was added to the undegassed water until the pH was 7.7 (1.0 ppm NH_3) there was still no pick up of copper.

These results with ammonia present are of particular interest because the opinion prevails that ammonia increases copper attack. Most data in the literature deals with high ammonia concentrations well above the range normally encountered in the power plant.

Power Plant Tests

A survey of the literature dealing with attack of copper or copper alloys has revealed that in most cases cited carbon dioxide was present with the ammonia. Many cases did not give the pH of the corroding waters and it is possible that in some instances the carbon dioxide was high enough to produce low pH values even in the presence of ammonia.

Severe corrosion was encountered in the after cooler section of the turbine air ejector of a central station. The first analyses were made for copper and ammonia in the drains from the after cooler and gave the following results:

	NH_3 ppm	Copper ppm
Turbine Condensate	0.64	0.2
After Cooler Drains	1.50	8.7

These results appeared to indicate that the copper attack was caused by the ammonia and increased rapidly as the ammonia increased. A further study in which the pH of the sample was obtained showed the turbine condensate to have a pH around 6.5 and an after-cooler drain pH of 5.3. This indicated low pH as the cause of the copper pick up and the ammonia might have had no appreciable action. In fact, if the carbon dioxide had been low the ammonia would have raised the pH and even protected the copper alloy tubes.

During September 1947 a survey was made of a central station operating at 900 psi on a condensing cycle with evaporated makeup. The water used in the evaporators and the condensing water was low in ammonia. There was a large amount of iron sludge in the boilers and this survey was made to determine whether the iron came from the boiler or the preboiler cycle. Samples of steam, condensate and boiler feed water were taken at regular intervals and the iron, ammonia and pH determined. The results showed a low pH in the steam with the value increasing as it went through the condenser and the boiler feed pump. The iron content increased as the steam and condensate passed through the cycle while the ammonia remained low and constant. This indicated that the iron was being dissolved as ferrous iron and was increasing the pH of the water. Ammonia was then added to the system as ammonium chloride. The dissolved salt was fed continuously along with sodium sulfite which was already in use. The ammonia was vaporized in the boiler and passed into the steam and the major portion was returned to the boiler in the feed water. Figure 3 shows that data collected both before and after the addition of the ammonia to the cycle. As the ammonia concentration was build up the pH of the steam increased and the iron pick up decreased. When the pH of the steam reached a value around 9.0 the iron pick up dropped to a very low value.

The ammonia addition was continued and is still in use on all units in this station. The amount of ammonia required to keep the pH of the feed water around 9.0 averages 50 grams NH_4Cl per day per boiler (500,000 pounds per hour steam generation). The ammonia in the fed water is 0.3 to 0.4 ppm. Samples collected from the after cooler drains on the air ejectors prior to adding the ammonia to the cycle gave the following results:

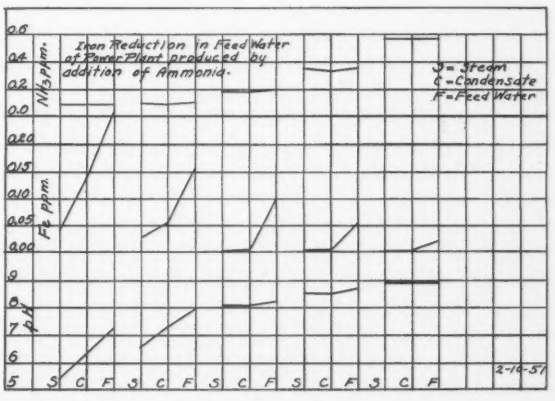
Iron Reduction in Feed Water at Power Plant produced by addition of Ammonia.
S=Steam
C=Condensate
F=Feed Water
NH3 ppm.
Fe ppm.
pH
S C F S C F S C F S C F S C F
2-10-51

Figure 3—Iron reduction in feedwater of power plant produced by addition of ammonia.

	pH	NH_3	Copper
After Cooler No. 1.....	6.75	0.80	0.55
After Cooler No. 2.....	7.30	0.70	0.25

Tests were run on the boiler feed water to study the effect of the ammonia on copper in the cycle but no copper could be detected. After adding the ammonia to the cycle the following results were obtained:

	pH	NH_3	Copper
After Cooler No. 1.....	8.0	1.04	0.00
After Cooler No. 2.....	8.7	1.76	0.00

These results indicated that the increase in ammonia also reduced the copper pick up. These drains are now being returned to the cycle and not wasted.

In another plant using ammonia treatment, samples from the after cooler drains were analysed with the following results:

pH	NH_3	Cu	Iron
9.6	11.0	0.00	0.01
9.5	6.2	0.00	0.00
9.5	9.1	0.00	0.01

The much higher values of ammonia in the drains were not causing any copper pick up. These drains were also returned to the cycle.

Ammonia treatment for control of steam and feed water pH has been in continuous use at this station since September 1947. Examination of the interior of the boilers during annual inspection has shown the iron and copper sludges in the boilers to be reduced to an extremely small amount.

Since starting the ammonia addition at this station the treatment has been used in seven other stations with steam pressure ranges from 600 to 1500 psi. In all these stations the iron and copper pick up has been materially reduced. In several of these stations ammonium sulfate is being used to increase the sulfate in the boiler water. In several stations the daily ammonia demand is much higher because the after cooler drains are sent to waste.

Reducing Chemicals in Boiler Water

For years reducing chemicals have been used in boiler waters for the purpose of reacting with any dissolved oxygen entering the boiler and in this manner prevent oxygen corrosion in the boiler tubes. The chemical commonly used is sodium sulfite. It now appears that the sulfite is also reducing the copper and iron which might enter the boiler in the higher state of oxidation. Thus if copper and iron are dissolved in the condensate any contact with oxygen will oxidize the metal to the cupric and ferric forms. When the water is deaerated the dissolved oxygen may be removed but the metallic ions remain in their higher state of oxidation. When the metallic ions enter the boiler and come in contact with the boiler metal particularly in the areas of heat input they will react with the metal and start small corrosion areas. The reactions involved could be as follows:

$$Fe + 4Fe_2O_3 = 3Fe_3O_4 \quad (3$$

$$3Fe + 8CuO = 4Cu_2O + Fe_3O_4 \quad (4$$

$$Cu_2O = CuO + Cu \quad (5$$

$$3Fe + 4CuO = 4Cu + Fe_3O_4 \quad (6$$

Both of the metallic ions will tend to form magnetic oxide of iron at the expense of the boiler tube metal. Thus small areas of magnetic iron oxide are formed in direct contact with the boiler metal. These may be points for the adherence of more metal oxides and additional corrosion. The corrosion products form a barrier to heat transfer and the tube metal temperature increases to the point where the steam—iron reaction will proceed.

$$3Fe + 4H_2O = Fe_3O_4 + 4H_2 \quad (7$$

The tube attack is accelerated under the compact hard adherent magnetic oxide formed at the higher temperature. The hydrogen formed at the higher temperature penetrates and decarburizes the steel, resulting in the formation of methane. The methane causes inter-crystalline splitting in the areas of decarburization. This type of attack is commonly referred to as the plug type or brittle tube attack.

When a sufficient residual of sulfite is maintained in the boiler water the cupric copper will be reduced to the cuprous form by the sulfite as follows:

$$2CuO + Na_2SO_3 = Cu_2O + Na_2SO_4 \quad (8$$

$$Cu_2O = CuO + Cu \quad (5$$

It is possible for the ferric iron to react with the sulfite as follows:

$$3Fe_2O_3 + Na_2SO_3 = 2Fe_3O_4 + Na_2SO_4 \quad (9$$

The two metallic ions in their lower states of oxidation will no longer react with the iron to start corrosion areas.

It is possible for the sulfite concentration in the boiler water to be so low it will not reduce the cupric and ferric oxides in the main body of the boiler water. These materials may then even start corrosion spots on the boiler tubes. As the deposits form the boiler water salts start concentrating under the deposits due to inability of the water to sweep them away. The sulfite concentration then becomes high enough to start reducing the oxides and thus prevents the continuation of the reaction 7. The concentrated boiler waters may have enough sodium hydroxide to dissolve the protective film of Fe_3O_4 and keep exposing the metal to fresh attack. The reformation of Fe_3O_4 from this type of attack is not the hard compact adherent magnetic oxide but is a softer crystalline type which does not cause excessive metal temperature and subsequent hydrogen attack on the steel.

When the sulfite concentration is high enough in the boiler water the oxides are reduced prior to reaching the boiler heating surface and will not adhere to the heating surface and no area for the start of either type of corrosion will be present. This approach assumes that the dissolved metals are oxidized prior to reaching the boiler. It is possible that in some closed cycle plants the entrance of oxygen is reduced to a minimum and the metals remain in their lower state of oxidation. Such cycles should operate free from tube corrosion even in the absence of sulfite treatment. Where the higher oxides exist it may be necessary to maintain definite residuals of sulfite in the boiler water.

Tests have been conducted in the laboratory to study the amount of sulfite residual necessary for reduction of the oxides of iron and copper. It was found that when cupric copper was in a sulfite solution at a pH of 10.0 for 4 minutes a temperature of above 425° F was necessary to bring about a high percentage reduction of the cupric copper. At 450° F with a contact time of four minutes it was necessary to have a residual of 20 ppm Na_2SO_3 in order to have complete reduction of the cupric copper. This work is being continued in order to find limiting concentrations at other temperatures and to study the action in regard to ferric iron.

There are conditions of operation which appear to limit the amount of sulfite residual which may be carried in a boiler without liberating sulfur dioxide or hydrogen sulfide in the steam.[1] The presence of ammonia in the steam to maintain the desired pH will neutralize the acid effect of the sulfur dioxide. Some boilers operate with sulfite treatment without noticing an appreciable amount of either sulfur dioxide or hydrogen sulfide in the steam.

Conclusions

Under conditions of low pH, iron and copper are dissolved in condensate and boiler feed waters and when brought in contact with oxygen are oxidized to the ferric and cupric forms. When the pH of the water is in the range of 9.0 the pick up these metals is reduced to a low value. In central station closed cycle plants this increase in pH in the whole cycle may be accomplished by the use of ammonia. A suitable concentration of a reducing agent in the boiler water is necessary to reduce the ferric and cupric forms so as to prevent the corrosion of the boiler metal.

References

1. R. C. Alexander, and J. K. Rummel, *Trans ASME*, **72**, No. 5, 519 (1950).

DISCUSSION

Comments by Arthur M. Guy, Chemical Engineer, Commonwealth Associates, Inc., Jackson, Mich.: There has recently been considerable discussion regarding high pH and alkalinity, particularly in high pressure boilers. Some recent failures have been attributed to these causes and recommendations were made to reduce the pH to 10 or below in order to prevent furnace tube failures at welded sections. Professor Straub has described his recent work with a pH in the neighborhood of 9. It would be interesting to know whether or not any work has been done or are they contemplating to do any work with a pH in the neighborhood of 10 or 11.

The second item that comes to my mind is that a boiler has been described as consisting of an oxide film supported by tube metal. If we are to take advantage practically of this theoretical aspect and assume that water and/or steam will not attack the tube metal when protected by a uniform adherent protective coating, we are wondering if all of this work is justified.

Authors' Comment:

Mr. A. M. Guy's comments are interesting. While our paper does not specifically mention furnace tube failures at welded sections we have reported our experience with this type of failure. (Wall Tube Corrosion In Steam Generating Equipment Operation Around 1300 psi. F. G. Straub. *Trans. ASME*, 1947). This experience indicated that reduction of pH did not stop the corrosion, however maintenance of a definite reducing material in the boiler water did stop the corrosion.

The theoretical aspect of a perfect oxide film protecting the boiler metal appears correct. To take advantage practically of this means that we must maintain an environment within the boiler which will prevent the destruction of this protective film. Thus if the pH is low the boiler water would dissolve the film. An oxidizing condition within the boiler would change the film from the magnetic form to the ferric form which would not be protective.

Discussions

Testing Inhibitors of Brine Drippings Corrosion of Railway Tracks and Equipment. By G. M. Magee. *Corrosion*, **7**, No. 6, 186-188 (1951) June.

Discussion by Marc Darrin, Mutual Chemical Company, of America, Baltimore, Md.:

Saving transportation equipment through reduction of loss by corrosion is particularly important at this time. As Mr. Magee pointed out, loss due to corrosion from brine drippings amounts to about $12,000,000 each year. If this could be prevented, it would not only result in a saving for the railroads but would make available more metal for other civilian needs. Mr. Magee reported laboratory tests and track trials showing that this corrosion can be almost completely eliminated by adding a small amount of chromate. This is in agreement with our laboratory tests and the experience of other industries. However, because of possible toxic hazards, consideration of chromate has been abandoned by the railroads in favor of other chemicals which are less effective in preventing corrosion under the variety of conditions encountered in practice. Other inhibitors are effective within rather limited pH ranges, or in the absence of aeration, or in the absence of bimetallic contents, etc. Chromate is unaffected by these variables, and I feel that no satisfactory substitute will be found. Valuable time and material could be saved if efforts are directed toward making changes in refrigerator cars so as to adapt them to use chromate without possibility of food contamination.

With respect to toxicity, I would like to call attention to comments made at the St. Louis meeting of NACE,[1] to the effect that fear of chromate is due largely to lack of information. To the best of my knowledge, no one in this country has died from taking chromate into the stomach within the past fifty years. A high dosage is required to kill small animals. The comparatively dilute solution used for corrosion protection is not dangerous since rats can live on water containing 500 ppm.[2] Furthermore, chromate appears to be non-cumulative and is quickly eliminated. Its presence is immediately evident because of yellow color. For years much higher concentrations have been employed in ordinary refrigerating brine, and its use is recommended by the American Society of Refrigerating Engineers.[3]

The purpose of my comments is not to minimize possible hazards but to view them in a proper perspective. Of course, I urge precautions in handling strong solutions and to avoid breathing dust. Do not allow it to remain in contact with the skin; wash it off with plenty of water . . . precautions which apply to the handling of most chemicals.[4]

References

1. Discussion of paper by John A. Temmerman and Aaron Sterlin on "Control of Corrosion by Salt Used for De-Icing Highways." *Corrosion*, **6**, No. 12, 394 (1950) Dec.
2. W. G. Gross and B. G. Heller. "Chromates in Animal Nutrition," *J. Ind. Hygiene & Tox.* p. 52-56 (1946) March.
3. American Society of Refrigerating Engr., Cir. 10, p. 3 (1930); Marc Darrin. "Chromate Corrosion Inhibitors in Brine Systems." ASRE 1944 Corrosion Report, p. 21-27.
4. Marc Darrin. "Corrosion Inhibition with Chromate." *Oil & Gas J.*, p. 83 (1949) Jan. 13.

Author's Reply:

Mr. Darrin's comments on the use of chromate inhibitors are, in my opinion, factually correct. However, other factors influenced the decision against use of chromate as an inhibitor in the prevention of corrosion from brine drippings. Principal among these was the shippers' objections to the use of this toxic inhibitor, and these objections were based not so much on the fact that the chromate would actually cause death but upon the probability that law suits would be forthcoming as soon as it became common knowledge that chromate was being used for this purpose. While it might be possible to defend these suits, it would involve considerable cost and expense.

Since the sodium phosphate glass type of inhibitor has indicated equally good protection, and since it can be more economically used because no additional investment for equipment is required nor is there any expense for maintenance of filters or other devices, it is our conclusion that the use of this type of inhibitor is more desirable.

●

Some Applications of Corrosion Inhibitors in the Petroleum Industry. By C. M. Blair, Jr. *Corrosion*, **7**, No. 6, 189-195 (1951) June.

Comments by H. E. Waldrip, Gulf Oil Corp., Houston, Texas:

Using the drop-size ratio method of determining wettability of treated crude oil, our laboratory selects the most efficient inhibitor and recommends concentration for field treatment. At present on some of our more corrosive sweet oil wells and most difficult oil to treat, the concentration used is one part of inhibitor to 1500 to 5000 parts of crude oil produced.

Some sweet crude oils lend themselves very readily to treatment and would require much less inhibitor but wells producing this type of crude are usually either non-corrosive or only mildly corrosive.

Author's Reply:

Although the corrosion problem in so-called sweet-

oil fields has received less notice than that occurring in sour oils, there is mounting evidence that corrosion in sweet-oil systems is more widespread than formerly thought. For example, corrosion of an extremely severe kind occurs in such sweet-oil fields as Smackover, Cayuga, Talco and parts of East Texas. In such fields, corrosion protection is obtained with organic inhibitors used in the concentration range given by Mr. Waldrip.

Comment by W. F. Oxford, Jr., Sun Oil Co., Beaumont, Texas:
Sun Oil Company is now using polar inhibitors at a treating rate of one stick/60 bbls. of condensate or one stick every other day and have reduced treating costs from $3.00/MMCF to 25c/MMCF.

Author's Comment:
Generally the amount of inhibitor required for a given degree of protection in a given system is a matter for experimental determination, but as a rough rule we have found that one stick of inhibitor per million cubic feet of gas produced will, after a short period of time, protect the most corrosive distillate wells. Many wells, however, are being protected at a rate of one stick to four million cubic feet of gas produced, a proportion which corresponds closely to the rate given by Mr. Oxford for the Sun wells.

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Materials of Construction for Handling Sulfuric Acid. NACE Technical Practices Committee Report TP-5A—Materials, Handling and Manufacturing Sulfuric Acid. By Spencer W. Shepard. *Corrosion* 7, No. 8, 279-282 (1951) Aug.

Comments by M. A. Scheil, A. O. Smith Corp., Milwaukee, Wis.:
The writer mentioned after the paper was given that the author, Mr. S. W. Shepard, did not mention a new rolled alloy called Hastelloy F which contains approximately 40-45% nickel, 20-22% chromium, 5-6% molybdenum, 1.35% columbium, and .75% tantalum, as a serviceable material for sulfuric acid. This material has been used by the writer in the vapor zone of sulfite digesters where high concentrations of sulfurous acid and sulfur dioxide gases are present at temperatures above 300° F and corresponding pressures. The alloy, from several extended service tests, appears to be quite free from pitting which is experienced in other stainless steel compositions containing approximately 3 to 4% molybdenum with chromium and nickel. Corrosion tests in boiling 5%, 10%, 15% and 20% sulfuric acid (by weight) solutions indicate corrosion rates of the order of .030 to .050 ipy. This material is weldable by the inert arc or by metallic electrodes which produce deposits of similar composition and similar corrosion resistance. It would be of interest to have any experience of the author on this material.

Author's Comment:
We have had no experience with Hastelloy F. From your comments this should be a quite interesting material of construction for handling sulfuric acid.

Questions by R. P. Lee, National Lead Co., Titanium Div., South Amboy, N. J.:
Have you any knowledge of the use of baked phenolic coatings on the exterior of concentrated H_2SO_4 coolers? What are heat transfer properties? It may be possible to coat the cooling sections and eliminate inhibitor use in the cooling water if heat transfer is good.

Author's Reply:
We have no knowledge of the use of baked phenolic coatings on the exterior of concentrated sulfuric acid coolers. The heat transfer of these coatings is not too bad and in general the overall heat transfer of such a system would not be changed materially. We have used the baked phenolic coatings on other types of heat transfer equipment satisfactorily.

Comment by Barclay Morrison, The Carpenter Steel Co., Union, N. J. (A similar comment was made also by L. M. Nieliwocki, DuPont Sabine River Works, Orange, Texas):
We wish to correct the impression given by the author that Carpenter wrough stainless steel No. 20 is not among the special sulfuric acid-resistant alloys. As a matter of fact, Carpenter No. 20 is the same alloy as Durimet No. 20 and its corrosion resistance to sulfuric acid in *all* concentrations below 176 degrees F is excellent.

Author's Comment:
I thank Mr. Morrison for correcting this impression if such an impression was made. We had not used the wrought stainless alloy for handling sulfuric acid, but it is certainly a logical material to use and we do appreciate its resistance to sulfuric acid solutions. We have used this alloy in the cast condition as Durimet 20 and Alloyco 20, etc., and know its resistance to a wide range of sulfuric acid conditions to be quite excellent.

Comment by William G. Renshaw, Allegheny Ludlum Steel Corp., Brackenridge, Pa.:
We notice that with the exception of mild steel this report covers resistance of the metals in pure sulfuric acid and solutions only. It might be worthwhile to mention here that our experience has shown small amounts of copper sulfate, dichromates, nitric acid or certain other inorganic salts present in sulfuric acid solutions will greatly increase the acid concentration limits within which the stainless steels can be satisfactorily employed. Such an example of inhibiting action is found in the case where stainless steel tanks and parts can be used for brass pickling operations because copper sulfate is formed during the process, while a pure sulfuric acid solution at the same temperature and concentration would cause attack of the tank.

It is probable that stainless steels are sometimes overlooked as materials of construction for sulfuric

acid applications because the inhibiting action of even small amounts of such substances may not be realized.

Author's Comments:

There is no doubt it is always wise to run corrosion tests to determine the rate of corrosion of various possible materials of construction because of the effect that impurities can have on the corrosion rates. It is well known that copper and other oxidizing inorganic materials tend to decrease the rate of corrosion on the stainless steels by sulfuric acid solutions. Some organic materials also decrease the corrosion rate appreciably.

Question by Albert K. Ackoff, Eastman Kodak Co., Rochester, N. Y.:

Would aluminum be suitable for ducts handling SO_2 and steam vapors from boiling tanks containing sodium bisulfite?

Author's Reply:

Aluminum has been used for ducts handling sulfur dioxide and steam vapors successfully. Aluminum is not too resistant to the alkaline sodium bisulfite so that precautions would have to be taken against spattering or entrained sodium bisulfite.

Comment by C. S. Brown, General Analine & Film Corp., Graselli, N. J.:

In regard to speaker's observation of vapor phase corrosion in sulfuric acid storage tanks, we have observed most serious corrosion in the bottoms of these tanks due to sludge formation. The best antidote to this attack seems to be frequent cleaning.

Author's Comment:

Our experience has indicated that vapor phase corrosion in sulfuric acid storage tanks has been more severe than the attack which takes place under sludge deposits on the bottom of the tanks. Removing the sludge would certainly be one way to help this condition, if the sludge can be removed without developing a weak acid condition during its removal, which might tend to accelerate corrosion.

Comment by A. J. Liebman, Dravo Corp., Pittsburgh, Pa.:

Industry needs information on the mixing of a low concentration of water into sulfuric acid at the tank to prevent acid attack on the upper one-third of the interior periphery of the tank. The attack lines are circumferential and appear like score marks.

Author's Reply:

The use of small amounts of water introduced into the vapor phase of sulfuric acid tanks would tend to reduce corrosion if the amount of water is sufficient to remove most of the sulfuric acid. Some of the difficulties involved are that if there is not a reasonable amount of agitation in the tank the vapor line corrosion may be increased because of dilution of the upper surface of the acid. If the storage tanks were run almost empty there might be sufficient dilution to secure sufficiently dilute acid so that high rates of corrosion might be encountered. We believe that it would be more desirable to consider using thicker sections in the upper one-third of the tank or to have the upper part of the tank protected with a protective coating, such as baked-on phenolic, an air dried vinyl, or metallized aluminum.

[EDITOR'S NOTE: Reports on a similar problem may be found in: Galvanic Action Between Lead, Worthite and Other Acid-Resistant Alloys in Sulfuric Acid. By W. E. Pratt and E. T. Collinsworth, Jr. *Corrosion*, **5**, No. 2, 39-44 (1949) Feb.]

●

High Pressure Sweet Oil Well Corrosion. By H. L. Bilhartz, *Corrosion*, **7**, No. 8, 256-264 (1951) Aug.

Comments by R. C. Buchan, Humble Oil & Refining Co., Houston, Texas:

Mr. Bilhartz' paper may give the impression to some that the type of corrosion under discussion occurs in only a few oil fields. Our experience has shown that it is prevalent in a large number of fields in Louisiana and Mississippi and is likely to occur in any deep high pressure wells where the carbon dioxide content of the gas is above about 0.8 percent, also, where corrosion is being encountered in condensate wells and oil production is closely associated with the condensate reservoirs, corrosion is likely to be found in oil wells. This is known to be true in Galveston Bay fields and in the North Katy Field in Texas. The latter field is a small one located on the north side of the much larger Katy gas field.

Organic inhibitors should be satisfactory for controlling this kind of corrosion. The application of inhibitors is difficult because the only practical way that they can be injected is via the casing. Where the fluid level stands high in the casing it may take one to possibly six months for the chemical to work its way around through the fluid and to the bottom of the well. In such instances, it is suggested that patience be exercised, particularly in view of the fact that the prevention of tubing corrosion is likely to be necessary in most cases for 10 to 20 years and the time required to start getting chemical protection, even though delayed for a few months, is not so important. One disadvantage in using organic inhibitors in this type of well is that the casing string is subjected to well pressure.

Comments by Rolland McFarland, Hills-McCanna Co., Chicago, Ill.

I asked for some clarification on the suitability of continuous feeders for inhibitor injection into corrosive wells. I remarked that information had reached us a number of times that all continuous operating, liquid feeders were found wanting in one way or the other when adding inhibitor to corrosive wells—and with the feeders giving trouble, largely due to clogging of the check valves and constant attention and maintenance. I further asked if anyone could offer experience or a case history where a liquid feeder was suitable, and the type of feeder used in that instance. Further, in view of the possible extent of application of such feeding devices, it

would appear that a good sized market would be open to the development and manufacture of a reliable feeding device. However, in the light of information received in the past, it would appear that the difficulties are almost insurmountable in meeting such a severe service application.

One of the group from the audience did reply to my question, but unfortunately I was not able to secure his name. This gentleman stated that within his experience every corrosive oil well had a chemical feeder included in the usual junk heap of equipment alongside the well and that his experience with continuous feeders had been unsatisfactory. His company corrected the situation by either using a homemade lubricator with balanced pressure for feeding the inhibitor or else used a large capacity, high pressure pump, truck-mounted and crew operated in order to make a continuous circuit of the wells requiring inhibitor and to periodically inject the inhibitor into the well with this large, intermittently operating pumping unit.

Question by W. F. Oxford Jr., Sun Oil Co., Beaumont, Texas:

Is it possible to screen corrosive from non-corrosive wells by use of drop-size ratio technique?

Author's Reply:

The question is pertinent but sufficient data are not yet available to provide the answer.

●

Bacterial Casing Corrosion in the Ventura Field. By Keith Doig and A. Wachter. *Corrosion*, **7**, No. 7, 212-224 (1951) July.

Comment by F. E. Kulman, Consolidated Edison Co. of New York, Inc.:

Studies of corrosion of steel gas mains in New York City show that severe corrosion is most likely to occur in dense, anaerobic, clay soils containing organic matter. Severe corrosion is less likely to occur in the sandy clay or clay soils. The hydrochloric acid test of corrosion products gives evidence of ferrous sulphide in 81 percent of all cases of severe pipe corrosion. The ferrous sulfide is the end product of microbiological sulfate reduction by anaerobic bacteria. Hence, bacterial action is the rule and not the exception in underground corrosion in this area.

A research project, now three years old, has for its object the investigation of the influence of the bacteria in corroding metals and of other soil microorganisms in deteriorating organic pipe coatings. Preliminary results have already been published.[1, 2] Samplings of the soil at various field sites showed the presence of three groups of sulfur bacteria, one iron and a nitrate reducing group. There was coexistence of aerobic and anaerobic bacteria, of forms that bring about oxidation and those concerned chiefly with reduction reactions. The sulfate reducing bacteria were found in soils at all test sites.

More recent investigation has shown that the seasonal variation of reducing bacteria may be related to variations in soil temperature, soil moisture content and pH. A tabulation of data at a typical test site, taken during March, May, July and October of 1949, is shown below:

Measurements at Test Site IV

	March	May	July	Oct.
Soil Temperature °C	8.	13	20	17
Moisture Content of Soil, percent	19.2	21.9	16.9	14.9
Soil Reaction (pH)	6.75	5.4	5.95	6.25
Bacteria count per ml, reducing species	1890	6250	577	14
Bacteria count per ml, oxidizing species	3390	3170	3140	2090
Organic Matter, percent	7.2	6.3	5.5	5.2

From these results and studies of leak records, it appears that corrosion becomes very active in the spring and early summer, several months before the highest soil temperatures are reached in the late summer. The counts of reducing bacteria were highest in the month of May and rapidly fell off during the summer.

Several mechanisms have been proposed for anaerobic bacterial corrosion, including Von Wolzogen Kuhr's theory of bacterial removal of polarizing hydrogen and the later concepts of differential-oxidation cells and the galvanic cell formed by iron and an incomplete film of bacteria-produced sulfide on the pipe surface. It would appear that further research may be required to investigate the exact mechanism of the corrosion process in order that the most effective remedies may be applied to counteract underground corrosion.

References

1. F. E. Kulman. Corrosion Control on High Pressure Gas Distribution System. Presented at the AGA Conference on Distribution, Motor Vehicles and Corrosion, Cincinnati, Ohio, April 4-6, 1949.
2. C. G. Deuber and F. E. Kulman. A Progress Report on Testing for Microbiological Damage of Underground Organic Coatings. Presented at the Conference on Electrical Insulation, National Research Council, Pocono Manor, Pa. November 7-9, 1949.

Question by H. L. Bilhartz, Atlantic Refining Co., Dallas, Texas:

Has consideration been given to the extent to which this theory might apply to fields other than Ventura?

Reply by Mr. Doig:

Little effort was made to obtain data for fields other than those on Ventura Anticline where the problem exists. External casing corrosion evidently occurs in other fields but the author does not know to what extent, if any, it is due to bacterial activity.

Questions by R. S. Wise, National Aluminate Corp., Chicago, Ill.:

1. What effect does downhole temperature have on growth of sulfate reducing bacteria?

2. Was any work done on the use of bactericides in the muds as an alternative to high pH mud?

Reply by Mr. Doig:

1. Apparently there is no effect because the leaks have occured at depths having temperatures from 80 degrees to 180 degrees F.

2. Some work was done, but because the bacteri-

cides were costly and had an adverse effect on mud properties, the study was not extensive.

Questions by Carl G. Deuber, Deuber Laboratories, New York, N. Y.:

1. What time elapsed before earliest evidence of anaerobic corrosion was observed?

2. Was there any evidence of seasonal trend to the onset of corrosion by the sulfate-reducing bacteria?

3. What was the time interval between completion of well and casing failure?

Replies by Mr. Doig:

1. Eleven months.

2. No. Seasonal effects on bacterial activity would presumably be related to soil temperature or moisture content. Because both of these become constant at relatively shallow depths, no seasonal effect was to be expected nor was any observed.

3. Times between completion and failure range from eleven months to 136 months, averaging about 55 months.

ERRATUM

(Supplying the corrected equation for that published on Page 255 in August, 1951 Issue.)

A Proposed Standard Method for Measuring the Electrical Resistance of Pipe Line Coatings. By Walter F. Rogers, B. H. Davis, Lyle Sheppard, L. G. Sharpe, E. R. Allen, Donald Bond and P. T. Miller. *Corrosion*, 7, No. 7, 245-251 (1951).

Substitute the equation below for the equation printed on Page 246, Column 2, immediately below Line 13:

$$K = \left(V - \frac{I\rho}{2\pi L} \ln \frac{r_2}{r_1}\right) \frac{L}{I}$$

The correction being that the ratio $\frac{L}{I}$ is substituted for the ratio $\frac{I}{N}$.

NACE REPRINT PRACTICE

Requests for prices on reprints of material appearing in CORROSION should be addressed to Norman Hamner, Managing Editor, National Association of Corrosion Engineers, 919 Milam Building, Houston 2, Texas. Prices usually cannot be given until after articles have appeared in CORROSION although requests for prices may be submitted at any time. Type from which technical articles are printed is kept standing for 90 days after date of issue, and reprints ordered during that interval will be from standing type. For reprints ordered after expiration of this period, write for details.

Permission to reprint articles usually is given to responsible firms and individuals who wish to have the work done themselves. NACE requires, however, that proper credit be given CORROSION at an appropriate place on all reprint material. The association also requests that reprint style closely conform to that approved by its board to be in keeping with the aims and objectives of the association and that copies of reprints made under this authority are supplied NACE for recording purposes.

Topic of the Month

Dynamically Testing Corrosion In Cooling Water Systems

By RALPH D. MILLER*

WATER TAKEN directly from a cooling system may be tested under operating conditions closely approximating those found in the plant operation through use of a laboratory dynamic corrosion tester. The water, including the desired inhibitor, can be controlled as to temperatures and flows and the rate or extent of corrosion of a given material ascertained quickly.

The increasing difficulty experienced by plants everywhere in finding sufficient cooling water is increasing the tendency to recirculating cooling water in towers or other systems. Corrosion from this cooling water frequently is of utmost concern and the addition of corrosion inhibitors to the stream is customary. There is a definite need for a quick method of testing inhibitor efficiency under conditions close to those in the circulating system itself. It is not only difficult, but also costly and time consuming to test inhibitors in the actual cooling tower.

The dynamic tester illustrated here was developed to provide a quick means of determining the effect of inhibitors in cooling water containing various concentrations of contaminants. Cooling water from the operating system itself may be used in this tester and operating conditions similar to those in the system may be maintained.

* Spencer Chemical Co., Pittsburgh, Kansas.

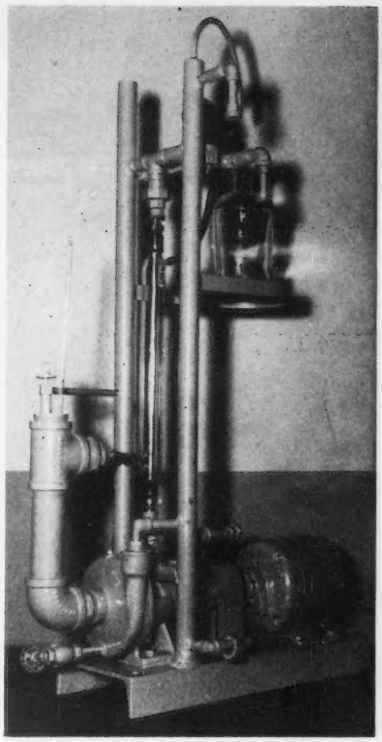


Figure 1—Laboratory dynamic corrosion tester.

The device shown in Figure 1 consists of a cooling water storage container, a heating surface, cooling surface and a circulating pump. Auxiliary equipment includes a thermostat for controlling the outlet temperature of the heated water, valves for adjusting the water flow through the system and cooling water flow to the cooler. Steam through the test section is controlled by a solenoid valve operated by a thermostat. With this equipment it is possible to take a given set of conditions and adjust the tester to produce the same conditions. If the inlet water temperature and outlet water temperature of plant equipment is known and the rate of water through the cooling section known, these conditions can be duplicated.

The amount of corrosion or scaling is measured in the test section. Any metal or alloy may be tested.

The test section generally used is a standard ¼-inch black iron pipe, lathe polished, with the surface activated. The area of exposed surface is measured and weight recorded. After the testing period the section is removed and if corrosion has occurred the corrosion product is removed and the section weighed. Loss may be measured in milligrams per square decimeter per day or in inches penetration per year, according to the operating data required.

The equipment is especially valuable in determining standard reactions to the effect of inhibitors at various concentrations. Monthly tests from each tower may be made monthly, for example, and adjustments made as indicated in the findings from these tests. Experience with this tester has proved its value in controlling inhibitors and corrosion in cooling water systems.

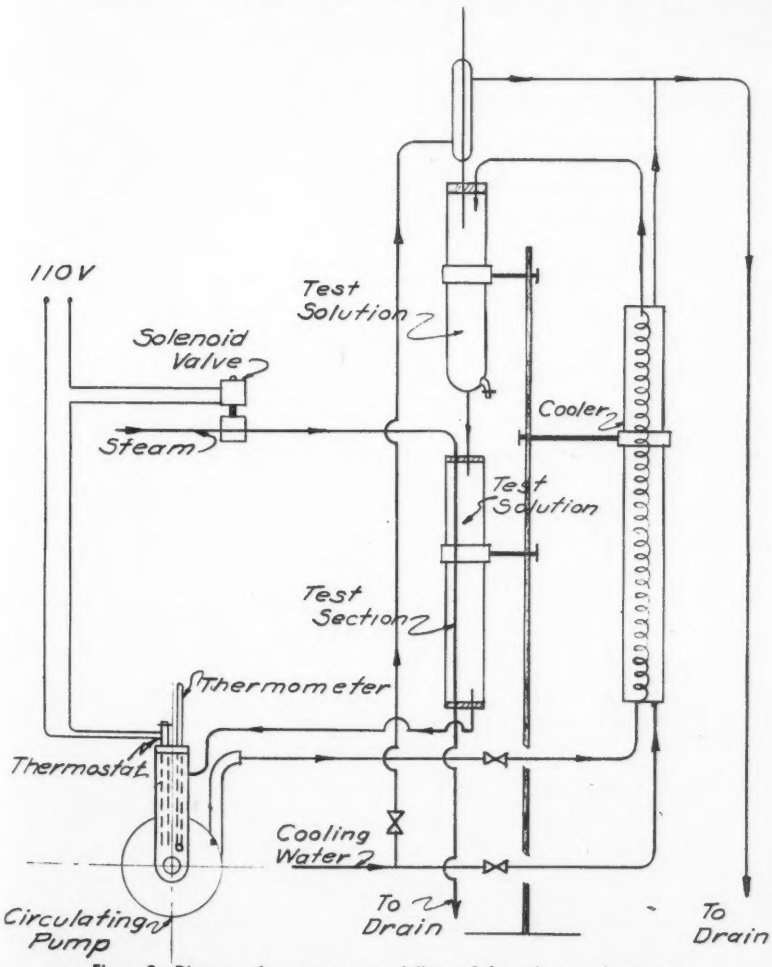


Figure 2—Diagram of arrangement and flows of dynamic corrosion tester.

NACE News

32 Papers, 8 Symposia Outlined for Galveston

OFFICERS OF SOUTHERN CALIFORNIA DISTRICT COUNCIL ASTM who will participate in the joint meeting on corrosion in which several engineering societies of the area, including NACE, are cooperating: Left to right—John T. Young, Los Angeles Bureau of Standards; C. M. Wakeman, chairman; Frank Galloway, Los Angeles Bureau of Standards; Myron Niesley, secretary; L. J. Markwardt, 1951 ASTM national president; Dr. William Barr, past national president ASTM, 1940-41, and C. L. Warwick, executive secretary, ASTM.

Participation by All NACE Members Urged

Thirty-two technical papers and eight symposia have been outlined for the 1952 Eighth Annual Conference and Exhibition of the National Association of Corrosion Engineers at Galveston, Texas, March 11-14. Robert L. Bullock, Technical Program Chairman, has named co-chairmen who have been assigned supervision over symposia. These are to name symposia officials.

Technical Program co-chairmen have been named to represent regions and the program is being organized to give every member of the association an opportunity to take an active part. Proposals for technical papers are welcomed. They should be addressed to the co-chairman in whose area the subject matter falls, with copies of correspondence to the technical program chairman and to Central Office, NACE.

Technical sessions are to be held from 9 to 11 a.m. and from 2:30 to 4:30 p.m. except Tuesday, first day of the meeting when a symposium on corrosion fundamentals is planned. The annual membership meeting usually is held on the first day of the conference also.

Technical Program Outline

The following program has been proposed:

Under George Best, Mutual Chemical Co. of America, 1348 Black St., Baltimore, Md.:
Electrical and Communication Industry, 4 papers.
Refinery Industry, 6 papers.
Marine Industry, 4 papers.

Under F. L. Whitney, Jr., Monsanto Chemical Co., 1700 South Second St., St. Louis, Mo.:
Chemical Industry, 6 papers.
Protective Coating Industry, 4 papers.

Under Derk Holstein, Shell Oil Company, P. O. Box 2527, Houston 1, Texas:
Oil and Gas Production Industry, 4 papers.
Oil and Gas Transportation and Storage Industries, 4 papers.

Under Norman Hackerman, Department of Chemistry, University of Texas, Austin, Texas:
Corrosion Fundamentals Symposium, 1 paper. (Also under consideration as an item on this program is the premiere showing of a corrosion motion picture.)

Other Regions Assist

Co-chairmen also have been named in

(Continued on Page 3)

Pierce Will Talk on Corrosion Resistant Masonry at New York

Robert R. Pierce, product supervisor, Pennsylvania Salt Manufacturing Co., Philadelphia, Pa. will address Metropolitan New York Section September 26 at Building Trades Employers' Association, 2 Park Ave., New York, on "Materials and Methods of Corrosion Resistant Construction with Masonry." Supplementing his talk will be a new motion picture showing the technique of carbon and ceramic brick lining construction as practiced in Germany. The film shows methods of installing large carbon and ceramic brick in a cylindrical digester vessel. Technical chairman of the meeting will be Arthur M. Clark, assistant engineer, Custodis Construction Co., New York.

The meeting is scheduled to begin at 6:30 p.m.

Silicone Developments Is Philadelphia Topic

Dr. R. R. McGregor of Mellon Institute will speak on "Recent Developments in the Use of Silicones," at a meeting of Philadelphia Section October 12. The meeting will be held at the Poor Richard Club. The film "Manhattan Spotlight" also will be shown.

Cleveland Section

Cleveland Section will hear an address on titanium by T. Kura of Batelle Memorial Institute at a meeting September 18.

NACE Membership Now Exceeds 3000

Membership in the National Association of Corrosion Engineers passed the 3000 mark as of the end of June with a total recorded of 3003. The July 31 total was 3057.

The predicted increase of about 50 members monthly for the balance of 1951 is expected to bring the year-end total to the vicinity of 3300.

Seagren to Represent NACE on Committee

G. W. Seagren, Mellon Institute of Industrial Research, Pittsburgh, Pa., has been named to succeed Frank L. LaQue of The International Nickel Co., Inc., as representative of the National Association of Corrosion Engineers on the Inter-Society Corrosion Committee. The other NACE representative is G. M. Shigley, The Dow Chemical Co., Freeport, Texas.

FREE ***Reprints While Supply Lasts***

***The Influence of Stress on Corrosion,* by Julius J. Harwood, Office of Naval Research, Washington, D. C. Reprinted from CORROSION, Vol. 6, No. 8 and and 9 (1950). A paper presented at the NACE meeting, St. Louis, Mo., April, 1950.**

Address your request to: Norman E. Hamner, Managing Editor, Corrosion, 919 Milam Bldg., Houston 2, Texas.

North Texas Outlines Fall Program Plans

Plans for meetings of North Texas Section NACE and other activities were discussed at an August 3 meeting of the executive committee and at a dinner business meeting for officers and committee chairmen August 27. The executive committee consists of H. L. Bilhartz, chairman; J. C. Spalding, vice-chairman and N. P. Chesnutt, secretary-treasurer.

Defining responsibilities of committees and consideration of a program schedule prepared by the executive committee was principal business of the August 27 meeting. An effort will be made to put tentative plans into effect prior to the first scheduled meeting in September.

The policy of the section will be to divide each program into two parts, the first of which will be devoted to either a "coffee speaker" who will discuss a subject foreign to corrosion or to a short motion picture which may or may not be related to corrosion. The second part will be presentation of a technical paper on some phase of corrosion. All meetings will be dinner meetings preceded by a half-hour fellowship period.

A. B. Campbell, executive secretary of NACE will address the September 10 meeting on "NACE — Its Organization, Functions and Achievements." Emphasis will be placed on the relations between local sections and the national organization. Answers to questions such as the following will be given: What can local sections expect from national? and What does national require of local sections in order to function at maximum efficiency.

Mr. Campbell's talk will be supplemented by a short teletranscription on corrosion filmed at the 1951 national conference at New York.

Two Chairmen Named

A. J. Liebman, The Dravo Corp., Pittsburgh, Pa. has accepted chairmanship of the Protective Coatings Symposium at the 1952 NACE Conference at Galveston and P. J. Gegner, Pittsburgh Plate Glass Co., Barberton, Ohio has accepted chairmanship of the Chemical Industry Symposium.

Officials Named for Galveston Arrangements

Chairmen and co-chairmen who will have charge of local arrangements for the Galveston Conference of the National Association of Corrosion Engineers March 11-14, 1952, have been named as follows by Charles G. Gribble, Jr., local arrangements chairman:

Printing Committee: Oliver Osborn, Dow Chemical Co., Freeport, chairman; J. B. Chatelain, Freeport Sulphur Co., Freeport, co-chairman.

Meeting Rooms Committee: Jack Battle, Humble Oil & Refining Co., chairman; Gordon Doremus, Cathodic Protection Service, co-chairman.

Registration Committee: A. L. Stegner, Tennessee Gas Transmission Co., chairman; Herschel Wood, Lebanon Steel Foundry, co-chairman.

Entertainment Committee: W. F. Oxford, Jr., Sun Oil Co., Beaumont, chairman; W. H. Stewart, Sun Oil Co., Beaumont, co-chairman.

Ladies' Entertainment Committee: W. H. Waring, Johns-Manville Co., chairman; Charles D. Brown, Aluminum Co. of America, co-chairman.

Publicity Committee: Elton Sterrett, The Pipeliner, chairman; Frank Love, Petroleum Engineering Publishing Co., Dallas, co-chairman.

Housing Committee: P. E. Darling, Pan American Refining Co., Texas City, chairman; Walter Janssen, Pan American Refining Co., Texas City, co-chairman.

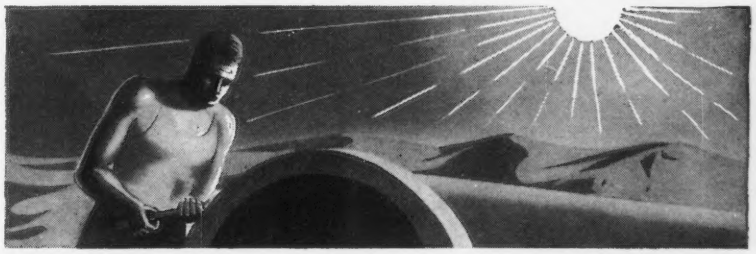
32 Papers—

(Continued from Page 2)

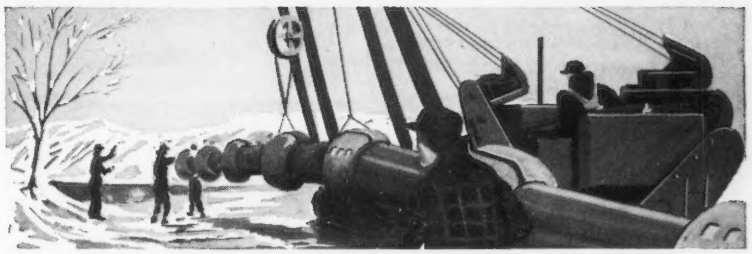
other NACE regions to cooperate in providing the program. Although no specific assignment of symposia has been made to these regions Mr. Bullock has asked cooperation with the others in seeking good technical material.

R. A. Davis of Chicago Bridge and Iron Company, 1500 North 50th St., Birmingham, Ala., has been named co-chairman for South East Region and David Hendrickson, East Bay Municipal Utility District, 512 Sixteenth St., Oakland, Cal., has been named co-chairman for Western Region.

Technical Practices Committees are asked to cooperate in their designated areas in supplying technical material.



From one extreme to the other



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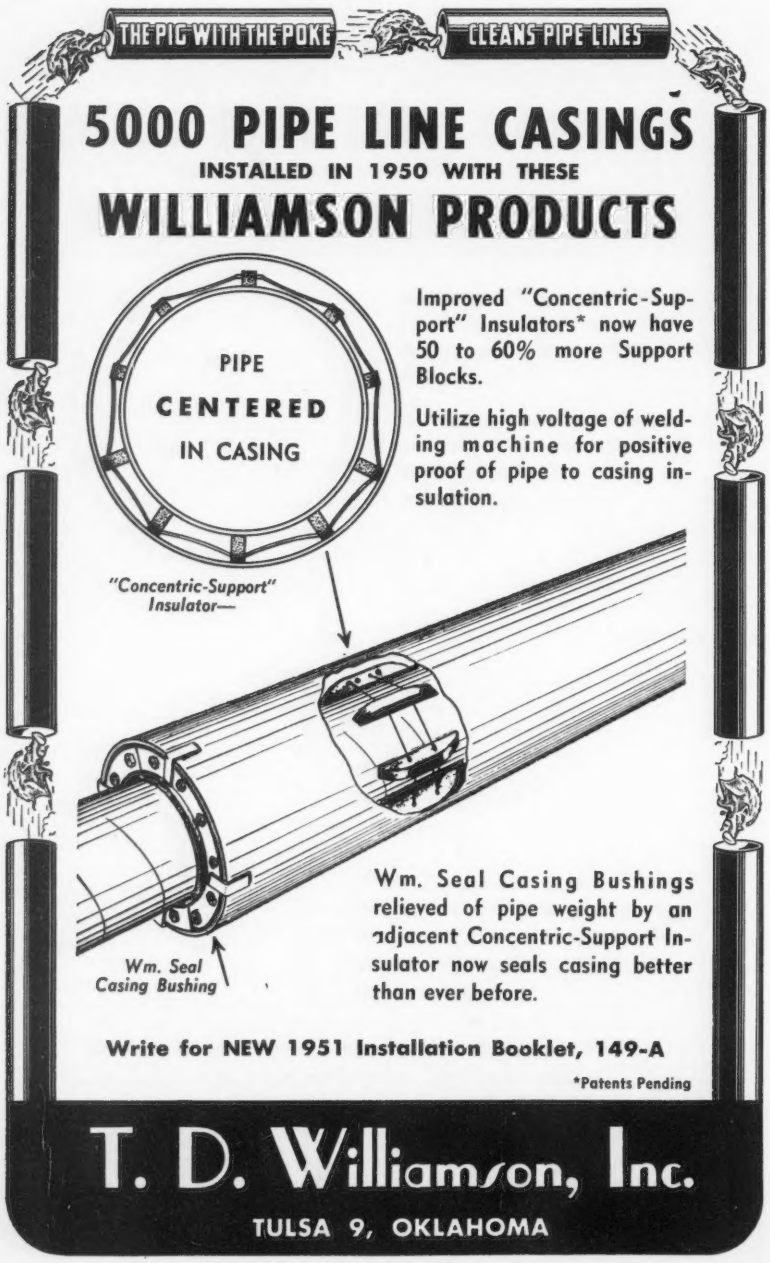
Jack P. Barrett Heads TP-6E Committee

Jack P. Barrett, Stanolind Oil and Gas Co., Tulsa, has been appointed chairman of TP-6E—Protective Coatings in Petroleum Production, by Kenneth Tator, chairman of TP-6—Protective Coatings. Mr. Barrett has been active in the work of TP-1—Corrosion of Oil and Gas Well Equipment and its sub-committees. His company experience and that secured at several Permian Basin Section Tank Coating Inspection Tours qualify him for chairmanship of the committee.

Chemical Conference Planned for Wilson Dam

A Southwide Chemical Conference will be held October 18-20, 1951 at Wilson Dam, Alabama under joint auspices of the American Chemical Society and the Southern Association of Science and Industry. Divisions of organic, analytical, industrial, physical and inorganic chemistry are contemplated. A Symposium on industrial wastes is scheduled. Additional information may be secured from Damon V. Royce, Chairman ACS, TVA Laboratories, Wilson Dam, Ala., or from H. M. Conway, Jr., director SASI, 5009 Peachtree Road, Atlanta, Ga.


THE PIG WITH THE POKE
CLEANS PIPE LINES
5000 PIPE LINE CASINGS
INSTALLED IN 1950 WITH THESE
WILLIAMSON PRODUCTS
PIPE
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Wagner To Be Given Palladium Medal

Dr. Carl Wagner, Visiting Professor of Metallurgy, Massachusetts Institute of Technology, will receive the first presentation of the Palladium Medal from The Electrochemical Society during the society's fall meeting at Detroit, October 9-12. Dr. Wagner is recognized internationally for his outstanding contributions to the theory of oxidation and tarnishing of metals. He is a native of Leipzig, Germany and has held numerous research and teaching posts in Europe. Following the war he became scientific adviser to the Ordnance Research and Development Division at Fort Bliss, Texas, where he remained four years. He joined Massachusetts Institute of Technology in 1949.

The Electrochemical society meeting at Detroit October 9-12 will include symposia on corrosion, electrodeposition, and electro-organic chemistry; round tables on screen engineering, power supply and requirements for the electrochemical industries, and primary and secondary batteries.

Plant trips are scheduled to The Dow Chemical Company, Midland, Mich., the Ford Motor Company's new filtration and disposal plant at Monroe and the engineering laboratories of Chrysler Corp.

Motion Pictures for Meetings Are Listed

Motion pictures which have been shown at national meetings of the National Association of Corrosion Engineers and which probably are available for showing at section or other meetings of the association are as follows:

Birth of an Oil Field—Shell Pipe Line Corp., Houston, Texas.

Building for the Nations—U. S. Steel Co.

Insul-Mastic in Industry—Insul-Mastic Corp. of America, Pittsburgh, Pa.

Flotation Painting of Water Sealed Gas Holders—Consolidated Edison Co. of New York, Inc.

Somastic Application—Bechtel Corp. and H. C. Price Co.

The following organizations also have motion pictures available for showing to engineering groups:

Allegheny Ludlum Steel Corp., Pittsburgh, Pa.

International Nickel Co., Inc., 67 Wall St., New York City.

Owens-Corning Fiberglas Corp., Toledo, Ohio.

A. O. Smith Corp., Milwaukee, Wis.

Formica Insulation Co., 4615 Spring Grove Ave., Cincinnati 32, Ohio.

Westinghouse Electric Corp., Box 2099, Pittsburgh, Pa.

TP-3 to Meet

Technical Practices Committee 3—Anodes for Use With Impressed Currents has scheduled a meeting to be held during the October 18-20 South Central Regional meeting at Corpus Christi.

Hot Dip Galvanizers Meeting Scheduled

The 1951 Semi-Annual Meeting of the American Hot Dip Galvanizers Association, Inc., will be held September 5-7 at the Greenbrier Hotel, White Sulphur Springs, West Virginia. Reports from the quality control, cost accounting, safety, membership, advertising, zinc situation and other committees are anticipated.

Addresses are scheduled by Herman Lind, president Industrial Fasteners Institute, Cleveland, Ohio; John G. Alexander, associate general counsel, National Production Authority, Washington, D. C.; Ralph Gieser, Engineering Laboratories, Rheem Manufacturing Co., Southgate, Cal., and G. A. Lux, technical education director, Oakite Products, Inc., New York.

ASTM 50th Meeting To Be at New York

The Fiftieth Anniversary Meeting of the American Society for Testing Materials will be held June 23-27, 1952, at New York City. The meeting will be centered at Hotel Statler.

Other ASTM meetings announced are:

1952 Spring Meeting and Committee Week—March 3-7, Hotel Statler, Cleveland, Ohio.

1953 Annual Meeting, June 21-25, Chalfonte-Haddon Hall, Atlantic City, N. J.

1953 Spring Meeting and Committee Week, March 2-6, Statler Hotel, Detroit, Mich.

1954 Annual Meeting and Exhibits, June 13-18, Sherman Hotel, Chicago, Ill.

1954 Spring Meeting and Committee Week, March 1-5, Shoreham Hotel, Washington, D. C.

The 1951 meeting of the American Society for Testing Materials held during the week of June 18 at Atlantic City, N. J., featured 23 technical sessions at which 110 technical papers were presented. Also held were 615 meetings of technical committees. Registered attendance was 2277, a new high figure.

About 75 specifications and tests were approved for reference to society letter ballot for adoption as standard. There are now about 1775 ASTM standards.

New officers of the association are T. S. Fuller, General Electric Co., Schenectady, N. Y., president; L. C. Beard, Jr., Socony-Vacuum Laboratories, New York City, vice president; and five new members of the board of directors are: J. W. Bolton, The Lunkenheimer Co., Cincinnati, Ohio; R. A. Schatzel, Rome Cable Corp., Rome, N. Y.; E. O. Slater, Smith-Emery Co., Los Angeles, Cal.; Stanton Walker, National Sand and Gravel Association, Washington, D. C., and F. P. Zimmerli, Barnes-Gibson-Raymond Division of Associated Spring Corp., Detroit, Mich.

Rohrman Resigns

F. A. Rohrman, chairman of TP-13—Annual Losses Due to Corrosion, has resigned chairmanship of the committee.

HALF-YEAR MEMBERSHIPS

NACE by-laws provide that those applying for Active (individual) Membership in the association subsequent to June 30 shall pay dues of $5 for the remainder of the calendar year.

- **The half-year membership includes issues of CORROSION magazine, July-December inclusive.**

News about the activities of organizations anywhere in the world engaged in corrosion mitigation are welcomed for use in the news section of CORROSION.

Booklets on Fulbright Awards Available

Two booklets, "The Fulbright Program" which explains the operation of the program under the provisions of the Fulbright Act and "1952-53 Program for University Lecturing and Post Doctoral Research Awards under the Fulbright Act," describing the openings for applications (except those for Greece and Turkey which will be issued later), are available for those interested in this program.

Openings are available in 10 European and Middle Eastern countries and in the United Kingdom and colonial dependencies.

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Ceramic Coatings Prevent Exhaust Gas Corrosion

AN INVESTIGATION of the corrosive effects of lead bromide vapors on various heat-resistant alloys, both with and without protective ceramic coatings, has recently been completed at the National Bureau of Standards. Lead bromide, which is the principal lead compound present in aircraft exhaust gases, has been suspected of contributing significantly to exhaust-system corrosion. Until now, however, available data bearing on this question have been few and inconclusive. The NBS investigation demonstrates that the uncoated alloys corrode fairly rapidly when exposed to lead bromide vapors at high temperatures, but that certain ceramic coatings effectively prevent corrosion under the same conditions. Sponsored by the National Advisory Committee for Aeronautics, the studies were conducted by Dwight G. Moore and Mary A. Mason of the NBS enameled metals laboratory.

Lead bromide is present in the exhaust gases of all engines that use leaded gasoline as a fuel. Aviation gasoline is more heavily leaded than automobile fuel, however, and aircraft exhaust temperatures are higher. For these reasons, corrosion from lead bromide is a greater possibility in aircraft than in automobiles. The fact that lead bromide vapors prove corrosive under certain conditions does not, of course, mean that leaded gasoline is undesirable as a motor fuel.

★ Technical Report 1544, National Bureau of Standards, U. S. Department of Commerce, Washington 25, D. C.

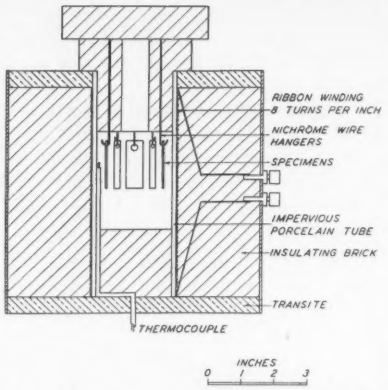

Figure 1—Cross-sectional drawing of the test furnace in which coated and uncoated alloy specimens were exposed, at the National Bureau of Standards, to the corrosive effects of lead bromide vapors at elevated temperatures. Ceramic coatings gave effective protection against lead bromide corrosion. In each set of tests eight specimens were suspended inside the furnace from a loose-fitting lid.

Reaction From Additives

The lead bromide found in exhaust gases results from the interaction of tetraethyl lead and ethylene dibromide, the active additives of leaded gasoline. The tetraethyl lead is added to improve combustion characteristics, while the ethylene dibromide acts as a scavenging agent. In this capacity the ethylene dibromide converts the lead oxide, which would otherwise be formed during combustion, into lead bromide. Lead bromide has a considerably higher vapor pressure than lead oxide and is therefore more readily passed through the exhaust system as a vapor.

Five heat-resisting alloys were investigated by NBS: Inconel (a high nickel alloy), Types 347 and 19-19DL stainless steels, Vitallium, and S-816. The first three alloys are in regular use in exhaust systems. Vitallium and S-816 are turbine blade alloys and, although too expensive for general exhaust system use, could be used for small critical parts. Specimens of each alloy with five different coating conditions were studied: an uncoated specimen, a preoxidized specimen, and three ceramic-coated specimens. The ceramic coatings, all commercially available, were NBS types A-417, A-19, and A-520. Specimens were exposed to lead bromide vapor for periods up to six hours in an air atmosphere at temperatures of 1350 degrees, 1500 degrees, and 1650 degrees F.

In the NBS investigation, a small furnace was first preheated to the desired temperature. After temperature equilibrium had been reached, the lid was re-

(Continued on Page 7)

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Ceramic Coatings—

(Continued from Page 6)

moved and a 1-gram charge of chemically pure lead bromide was dropped into the furnace. A second lid, from which eight alloy specimens were suspended, was then quickly put into position. This lid fitted loosely and allowed some air to diffuse into the furnace. Determination of the effectiveness of the ceramic coatings did not require that the lead bromide vapor concentration be kept constant.

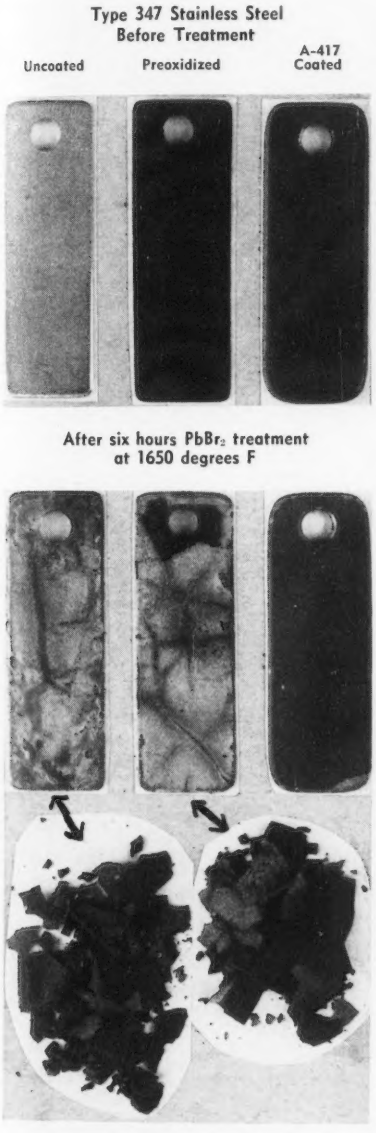

Figure 2—Appearance of uncoated, preoxidized and A-417 ceramic-coated specimens of Type 347 stainless steel before and after a 6-hour lead bromide vapor treatment at 1650 degrees F. A substantial amount of scale (bottom) dropped off the uncoated and preoxidized specimens after treatment. The ceramic-coated specimens were unaffected, however, except for slight flaking of the coating at a few points near the edge. This flaking occurred only after cooling and probably resulted from initially imperfect adhesion.

TABLE I
Loss in Thickness Under Various Test Conditions[a]

ALLOY	Coating	Loss in Thickness in Mils		
		1350 °F.	1500 °F.	1650 °F.
Inconel...	None	1.6[b]	6.2[b]	1.6[b]
	Oxide	0.9[b]	4.4[b]	1.5[b]
	A-417[c]	0.4	0.3	0.4
	A-520[c]	0	0	0.6
	A-19[c]	0	0.2	0.4
Type 347.	None	9.1	9.8	8.4
	Oxide	8.4	8.9	10.8
	A-417[c]	0	0.2	0.2
	A-520[c]	0.2	0.5	0.2
	A-19[c]	0	0.2	0
Type 19-9DL	None	9.9	10.1	10.2
	Oxide	5.8	8.1	10.7
	A-417[c]	0.4	1.1	1.0
	A-520[c]	0	0.7	0.3
	A-19[c]	0.2	0.5	0.5
Vitallium	None	3.7	3.5	2.4
	Oxide	2.5	2.2	1.5
	A-417[c]	0.1	1.0	0.3
	A-520[c]	0	0.5	0.6
	A-19[c]	0.2	0.6	0.5
S-816....	None	1.2	6.6	2.5
	Oxide	1.9	6.3	2.1
	A-417[c]	0	0.5	1.0
	A-520[c]	0	0.6	0.9
	A-19[c]	0.4	0.8	0.8

Charge Renewed Every Hour

Each batch of specimens was heated in the furnace for a total of six hours. At one-hour intervals, however, the specimens were removed, examined and then replaced together with a new charge of lead bromide. This hourly examination included cleaning of a limited area of the specimens—which were in the form of flat strips—and measuring the loss in metal thickness from corrosion. Loss in weight was also measured in some instances. At the end of the tests, cross-section of the specimens were studied microscopically, and both the scale layer and the cleaned alloy surface were examined spectrochemically for lead content.

Large differences in the resistance of the several alloys to attack by lead bromide were found; although all five uncoated alloys suffered corrosion at all test temperatures, the loss of thickness in the full 6-hour period ranged from 1.2 to 10.1 mills (Table 1). Alloys S-816, Vitallium and Inconel were notably more resistant than the 19-9DL and Type 347 stainless steels, both of which are high-iron, austenitic-type alloys. Microscopic examination indicated that a selective attack took place with the 19-9DL and 347 steels, leaving a spongy layer near the surface. With the other alloys, however, very little selective penetration was found.

Preoxidation Helps Little

Preoxidation of the surfaces of the alloys tended to retard corrosion for the first hour or two only, after which corrosion proceeded at an undiminished rate. Preoxidation was accomplished by heating specimens in air for four hours at the test temperature.

No consistent relation was found between temperature and rate of corrosion; some but not all of the alloys showed less corrosion at the higher temperatures. Similar results have been reported by other investigators of alloy corrosion and are apparently not unusual. However, it must be remembered that in the NBS test method the lead bromide concentration probably dropped off more rapidly with time at higher

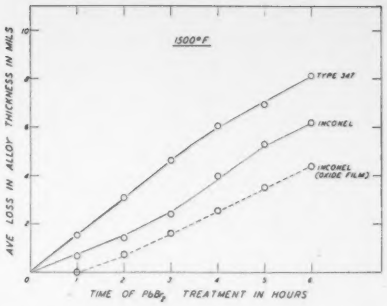

Figure 3—Loss in thickness plotted against time of exposure for three specimens in recent NBS corrosion tests. The specimens were treated six hours at 1500 degrees F with lead bromide vapor in an air atmosphere. Measurements were made at hourly intervals. As was typical, the preoxidized specimen showed resistance to corrosion only at the beginning of the test period; after the first hour or two corrosion proceeded at about the same rate as without preoxidation. The curves for the coated specimens fall along the time axis.

temperatures than at lower temperatures. Thus at 1650°F a 1-gram charge of lead bromide may have left the furnace as vapor in a few minutes, whereas at the lower temperatures a 1-gram charge probably fed vapor into the furnace atmosphere throughout the entire 1-hour heating period.

NOTE: For information on an earlier related development at NBS, see High-temperature Ceramic Coatings for Molybdenum. NBS Tech. News Bull., **32,** 125 (1948).

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JOINT ELECTROLYSIS COMMITTEE OF THE VARIOUS UTILITIES, CHICAGO, ILL.—Shown above at a May 6 meeting are members and associates of this committee representing traction, gas, water, electric and communication interests. Left to right, seated: A. J. Rio, L. Mauel, L. C. Eddy, M. D. Fletcher, J. L. Adkins, M. B. Hart, C. J. Buck, J. Svetlik, W. E. Nelson, E. H. Phillips and R. R. Wasson. Standing: A. Buck, F. K. Gleason, L. M. Plym, V. J. Payton, P. L. Janke, R. I. Perry and E. B. Hager.

Electrolysis Committee Was Organized in Chicago in 1908

The first joint electrolysis committee organized in a city in the United States came into being in Chicago in 1908. The committee, although it has undergone several reorganizations, is in effect still in being and active in electrolysis and corrosion work. The present group, called the Joint Electrolysis Committee of the Various Utilities, has members representing traction, gas, water, electric and communication interests.

The committee currently is seriously concerned over the corrosion caused by salt used for de-icing streets, but to date has found no satisfactory solution. Meetings are held on an average of once every two months, called at the request of the president or any member, and offer opportunities to present corrosion problems for discussion and advice. Announcements are made of joint tests and proposed drainage installations which may affect other utilities. The traction companies also advise the committee of proposed changes in operation of substations and track layouts or removals.

M. B. Hart of Illinois Bell Telephone Company is chairman.

BOOK REVIEWS

REPORT OF THIRD ANNUAL CORROSION TOUR. Permian Basin Section, National Association of Corrosion Engineers. 44 pages, 8½ x 11 inch mimeographed sheets. Available from C. O. Bundrant, The Western Company, P. O. Box 310, Midland, Texas. Per Copy.....$1.00

Consists of reports on the examinations of tanks and other structures during the September 27-30, 1949, Third Annual Corrosion Inspection Tour conducted by Permian Basin Section, National Association of Corrosion Engineers. The reports consist of remarks giving the age, composition of structure, protective system used, characteristics of corrosive and service data followed by a comment on what inspection of the structure revealed.

MEMBERSHIP CARDS AVAILABLE

Association members in good standing will be issued on request a membership card in the National Association of Corrosion Engineers. Address requests to A. B. Campbell, Executive Secretary, 919 Milam Building, Houston 2, Texas.

Welding Society Will Test Sprayed Metal

An extensive testing program to determine what thickness of zinc or aluminum sprayed coatings should be used for various exposures and times is under way under the American Welding Society's Committee on Metallizing. Preparation of more than 4000 specimens to be exposed is under way. Duplicate steel specimens will be sprayed with aluminum and zinc coatings varying in thickness from 0.003 to 0.015-inch with and without vinyl cover coats.

When the specimens are completed they will be exposed at standard test sites including Kure Beach, N. C.; Point Reyes, Cal.; the Gulf Coast, New York City and Wrightsville Beach, N. C. Exposure periods will be from one to 12 years.

Copies of the program and periodical progress reports may be obtained from Secretary, American Welding Society Committee on Metallizing, 33 West 39th St., New York 18, N. Y.

Dedication of Illinois Water Laboratory Set

Dedication of new laboratory and office building of the State Water Survey Division of the Illinois Department of Registration and Education on the campus of the University of Illinois, Champagne-Urbana will be held October 1-3. A conference divided into hydrology, water treatment and radarmeteorology will be held. A dedication dinner will be held October 2 and several field trips have been arranged.

Publications Exchanged

The Institution of Mechanical Engineers, Storey's Gate, St. James Park, London, has agreed to exchange its publications for CORROSION effective with Vol. 164, No. 1 of its Proceedings. War Emergency Proceedings and Automobile Division Proceedings all will be sent to Central Office NACE where they will be used for reference and abstracting purposes.

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Notices of meetings to be held by NACE subdivisions will be carried in the "NACE Calendar" if received in time.

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Corrosion Problems

E. A. TICE, Editor

Corrosion Engineering Section, The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.

Submit questions and answers for this column in duplicate to the editor. All questions become property of NACE. Questions and Answers may or may not be published under this heading, and may at discretion, be answered by mail directly. Answers to questions are solicited. Authors of questions will remain anonymous to readers while authors of answers may remain anonymous if they request it.

QUESTION

No. 15 — Strong sulfuric acid can be handled in iron and steel equipment in concentrations ranging from 100 percent down to approximately 80 percent. Below that concentration the acid becomes progressively more corrosive to ferrous materials. Experience indicates that recovered acid at concentrations as low as 50-50 percent, as encountered in the petroleum and petro-chemical industries, is substantially noncorrosive to carbon steel and cast iron. It is assumed that this behavior is due to the presence in these recovered acids of substantial amounts of organic matter which is capable of acting as an oxygen consumer and/or corrosion inhibitor.

a) What are the limiting concentrations and temperatures between which iron and steel can be used with those recovered acids?

b) Is organic matter *per se* responsible or is the character of the organic matter critical? In other words, do the recovered acids from different industries in this general group behave differently?

ANSWER

a) It has been our experience that sulfuric acid recovered in petroleum refining processes can be handled satisfactorily in iron and steel equipment at acid concentrations of from 70 to 98 percent and temperatures up to 120 degrees F. At acid concentrations in the range of 70 to 77 percent an increase in temperature up to 175 degrees F increases the corrosion rate only slightly; while in the concentration range of 80 to 90 percent an increase in temperature causes a very large increase in corrosion rate.

b) Recovered acids from petroleum refining processes vary widely in their tendency to corrode steel. This is thought to indicate that the type of organic material present in the acid is critical in determining whether the corrosion reactions are inhibited.—By Sherman S. Shaffer, Humble Oil & Refining Company, Baytown, Texas.

QUESTION

No. 47 — Does the use of formaldehyde as an inhibitor of corrosion have any application in petroleum refineries?

ANSWER

Formaldehyde has little if any application as a corrosion inhibitor in petroleum refineries. More effective inhibitors are available commercially.—By Sherman S. Shaffer, Humble Oil & Refining Company, Baytown, Texas.

QUESTION

No. 57 — At the present time, we are using 12-gauge steel tubes in the air preheaters of our cracking still furnaces. These tubes are 3 inches OD and 9-feet long. In five months' service we find that the top two feet, the cooler end, corrodes away due to the presence of sulfur dioxide and trioxide in our flue gases. Some of the tubes have become plugged with iron sulfate, the plugging occurring just below the corroded end.

The temperature of the flue gases entering the preheater is about 100 degrees F and the outlet temperature 700 degrees F. The fresh air enters at atmospheric temperature and leaves at 500 degrees F, the flow being counter current. Is there an alloy which will give us considerably longer preheater tube life? Is there an economical chemical means of neutralization of the corrosive gases or a coating which would protect the steel?

ANSWER

From the description of the corrosion experienced on the flue gas side of the air preheater tubes it appears that the corrosion is due to condensation of water on the cool ends of the tubes accompanied by the absorption of SO_2 and SO_3 from the flue gases. This could result from the preheater tubes being cooled to the dew point of the combustion gases by the entering fresh air. A possible solution would be to reduce the quantity of fresh air flowing through the preheater, so that the metal is not cooled below the dew point of the flue gas. No suggestion can be offered as to a more suitable alloy or a protective coating for the

(Continued on Page 10)

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Corrosion Problems—

(Continued from Page 9)

tubes. It is not thought to be economically feasible to neutralize the corrosive gases.—By Sherman S. Shaffer, Humble Oil & Refining Company, Baytown, Texas.

QUESTION

No. 84 — In view of the current demands for critical corrosion resistant materials the use of electroplated coatings to replace solid alloy equipment for chemical processing and shipping units could greatly conserve metal. Has the art of nickel plating progressed to the point where nickel coatings, deposited either electrically or chemically, can be used as a substitute for solid nickel in services such as hot caustic soda solutions?

ANSWER

The answer to this question is "yes," providing the thickness is adequate to overcome porosity prevalent in thin coatings. Thicknesses of the order of 5 mils will usually be sufficient for overcoming porosity on surfaces usually found in this field of application. Adequate amounts over this minimum are to be provided for corrosion protection based on calculated rates of corrosion for commercially pure wrought nickel.

Example: Field corrosion test for 52 days in 73 percent caustic storage at 230° F average.

Indicated Corrosion

Material	Rate, IPY
Wrought Nickel	0.00005
Nickel Plated Steel, 0.001" Ni	0.00036
Nickel Plated Steel, 0.003" Ni	0.00012
Nickel Plated Steel, 0.010" Ni	0.00006
Mild Steel	0.010

The advantages and disadvantages of the several methods of depositing nickel coatings are listed below:

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4. More economical deposit.

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3. As far as it has been determined, porosity for a given thickness is about equal for the two methods of deposition.
4. Chemical reduction or "Electroless" plating method has the primary disadvantage in that the coating contains at least 3 percent phosphorous and may contain as much as 11 percent without loss of metallic appearance of the coating. The deposit is brittle but if the phosphorous content is not too high it becomes ductile upon heating. Coatings of several mils thickness can be obtained. By H. O. Teeple, The International Nickel Company, New York, New York.

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CORROSION published in December, 1950 indices to all technical material published in the magazine from 1945 through 1950.

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Clippings on Corrosion

Extracted from Current Periodicals

CORRODED TELEPHONE CABLE TO BE REPLACED

(From Little Rock, Ark. *Gazette,* June 9, 1951)

About 250 feet of a telephone cable serving 2575 telephones in downtown Little Rock and North Little Rock is being replaced.

•

BRIDGE CLOSED 16 DAYS FOR REPAIRS IN OHIO

(From Columbus, Ohio *Dispatch,* June 17, 1951)

The Grandview Ave. bridge over the Scioto River was reopened June 16 after being closed since May 31 for repairs to corrosion-weakened steel stringers and for resurfacing.

•

WARNING ON POISONOUS WATER VAPORS DISPUTED

(From N. Y. *World-Telegram & Sun,* June 22, 1951)

W. J. Ryan, technical manager of Water Service Laboratories, Inc., disputed conclusions in a letter in which the writer stated chemical compounds used in boiler water treatment contain chromite which is highly poisonous and that any steam that escapes from boilers using chromite is dangerous and can contaminate food. Ryan said "chromite" is not used in treating boiler water, and sodium chromate seldom if ever is used because other chemicals are cheaper and as effective. The chemicals used in boiler water treatment are non-volatile and remain in solution in the boiler water.

•

CORROSION IS DANGER IN HOME PRESSURE CANNERS

(From Moberly, Mo. *Monitor-Index,* June 13, 1951)

Home pressure canners can be used with safety if the safety valve is kept clean and free from corrosion.

•

SMOKE DAMAGE TO N. Y. $150 MILLION ANNUALLY

(From N. Y. *World-Telegram & Sun,* July 18, 1951)

Caustic sulfur fumes that cause newly painted surfaces to crack and peel, steel window casements to rust, and graying of building marble cause part of the estimated $150 million annual smoke damage to New York City property, it is believed by the Coal Consumers Protective Association.

•

ARKANSAS INCREASES SULFUR PRODUCTION

(From Monette, Ark. *Sun,* June 21, 1951)

The McKamie-Patton Co., a producer of natural gas near Lewisville, Ark., is taking 150 tons of sulfur daily from hydrogen sulfide stripped from gas from its wells. When a third plant goes into operation near Magnolia by Lion Oil Company, sulfur production from Arkansas will be about 50,000 tons annually, with a value of $1,500,000.

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NACE

New Members and Changes of Address

- This list is published principally for use by NACE Regional and Sectional officers in keeping their mailing lists up to date.

NEW MEMBERS

(Additions Through July 27, 1951)

CALIFORNIA

CULLEN, THOMAS G., Texture Coatings, Inc., 21 Las Vegas, Orinda, Cal.
EFFINGER, R. T., Shell Oil Co., Martinez Refinery, Martinez, Cal.
HEDRICK, H. M., 310 Termino, Long Beach, Cal.
HILL, PRESTON W., Signal Oil & Gas Co., 2301 E. Willow, Long Beach, Cal.
MARTIN, W. EDGAR, Edgar Martin Co., 50 Hawthorne St., San Francisco 5, Cal.
RIDOUT, ROBERT P., Southern Counties Gas Co., P. O. Box 217, Foy Station, Los Angeles 17, Cal.
TUNE, NEWELL W., 556 North Orlando Ave., Los Angeles 48, Cal.

CONNECTICUT

GOTTLIEBSEN, LENIUS H., General Electric Co., 1285 Boston Ave., Bridgeport 2, Conn.

FLORIDA

LOGAN, CAMPBELL F., Logan Diving & Salvage Co., 309 Consolidated Bldg., Jacksonville, Fla.

GEORGIA

SMITH, WILLIAM A., Dixie Paint & Varnish Co., Inc., P. O. Box 256, Brunswick, Ga.

ILLINOIS

POTTS, PHILLIP E., Sinclair Pipe Line Co., Box 631, Galesburg Ill.
SERBULA, STEVE, JR., Allied Industrial Supply Co., 2345 N. Cicero Ave., Chicago 39, Ill.
WASSON, ROBERT R., Illinois Bell Telephone Co., 311 W. Washington Street, Chicago, Ill.

INDIANA

DURMAN, FREDERICK P., Central Indiana Gas Co., 20th and Monroe Sts., Muncie, Ind.
MANKIN, PAUL A., Bowser, Inc., 1302 E. Creighton Ave., Fort Wayne, Ind.

KANSAS

PURSELL, WALTER L., Skelly Oil Co., Box 1121, El Dorado, Kan.

LOUISIANA

SCHALLER, CHARLES C., Schaller Steel Works, Inc., 2201 France, New Orleans 17, La.

MASSACHUSETTS

KELLEY, HOWARD M., Chemical Fire & Rust Proofing Corp., 84½ Berkeley St., Boston, Mass.

MICHIGAN

KEPLEY, CHARLES L., A & P Finishing & Manufacturing Co., 17760 Clarann, Melvindale, Mich.
MAHONEY, E. J., JR., Mahoney Contracting Co., 2300 N. Grand River, Lansing, Mich.

MINNESOTA

NIEDERLOH, EARL L., Gray Co., Inc., 60 Eleventh Ave., Northeast, Minneapolis 13, Minn.

MISSOURI

MONTGOMERY, CLYDE W., Missouri Paint & Varnish Co., 5125 North 2nd St., St. Louis 7, Mo.

NEBRASKA

MURPHY, ASHLEY T., Corps Engineers, U. S. Army, Faidley Bldg., Omaha, Neb.

NEW JERSEY

ALLEN, R. J., Worthington Pump & Machinery Corp., 401 Worthington Ave., Harrison, New Jersey.
NORCOM, GEORGE D., 118 Conover Lane, Red Bank, Monmouth County, N. J.

NEW YORK

COLLINS, WILLIAM J., Corning Glass Works, Engineering Bldg., Tioga Ave., Corning, N. Y.
ENNIS, HERBERT E., United States Plywood Corp., 55 W. 44th Street, New York, N. Y.
McDERMOTT, FRANKLIN, Lever Brothers Co., 80 Varick St., New York 13, N. Y.
TARQUINEE, VAL, Arabian American Oil Co., 505 Park Ave., New York 22, N. Y.
WELCH, WILLIAM, JR., Long Island Lighting Co., 250 Old Country Rd., Mineola, N. Y.

OHIO

ELLIS, MURRAY P., The Barrett Div., Allied Chem. Dye Corp., 117 Mentor Ave., Painesville, O.
SEXTON, EARL M., Ohio Bell Telephone Co., 121 Huron St., Toledo, O.
WALTERS, WALLY Z., 2912 Woodside Place, Cincinnati, O.

OKLAHOMA

CULBERTSON, J. L., 8008 E. 21st St., Tulsa 15, Okla.
JOHNSON, FELIX M., The Trojan Construction Co., Inc., 1416½ N. Robinson, Oklahoma City 3, Okla.
PARKHILL, ROY F., Parkhill Truck Co., P. O. Box 1856, Tulsa, Okla.

PENNSYLVANIA

COPELAND, RAYMOND D., Pipe Line Service Corp., Factory St., Glenwillard, Penn.
DOWNING, W. E., Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Penn.

TEXAS

ALLMEN, JOHN VON, Corpus Christi Gasket & Packing Co., P. O. Box 4074, Corpus Christi, Texas.
BAKER, JOHN E., 2201 N. Washington, Odessa, Tex.
BRUSSEE, LESTER W., Industrial Waterproofing Co., 2318 Sul Ross, Houston, Tex.

(Continued on Page 12)

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New Members—

(Continued from Page 11)

DAY, STEPHEN D., S. D. Day Co., 1973 W. Gray Ave., Houston, Tex.
FAVROT, LAURENCE H., Houston Contracting Co., 2707 Ferndale Place, Houston 6, Tex.
FRENCH, JOHN W., Phillips Chemical Co., Plains Plant, Copalymer Section, Borger, Tex.
GARNER, CORDELLE L., Tube Kote, Inc., 2520 Holmes Road, Houston, Tex.
HAMLIN, GEORGE O., Hamlin Painting Co., Box 697, Aransas Pass, Tex.
MILLS, E. J., Sunray Oil Corp., Box 1168, Snyder, Tex.
NICHOLS, WILLIAM D., The Texas Pipeline Co., P. O. Box 2332, Houston 1, Tex.
RENCH, JOSEPH E., JR., Napko Paint & Varnish Works, Box 9145, Houston, Tex.
RICHARDS, S. L., JR., Rosson-Richards Co., 801 M & M Bldg., Houston, Tex.
SCHMIDT, FRED A., The Texas Pipeline Co., P. O. Box 2332, Houston 1, Tex.

WISCONSIN

GEISSINGER, RICHARD M., 6140 W. Appleton Ave., Milwaukee 10, Wis.
HERTEL, WALLACE E., Wisconsin Southern Gas Co., 235 Broad St., Lake Geneva, Wis.
KOEHLER, DONALD N., Milwaukee Gas Light Co., 626 E. Wisconsin Ave., Milwaukee, Wis.
VAHLDIECK, NATHAN P., Allis Chalmers Manufacturing Co., P. O. Box 512, Milwaukee 1, Wis.

FOREIGN

BOWMAN, MACK M., Colombian Petroleum Co., Apartado 100, Cucuta Colombia, S. A.
LATAILLE, LESTER W., 139 Nano Way, Honolulu No. 15, T. H.
MARTINEZ, FELIX G., PADRON, Cuban Telephone Co., Aguila Y Dragones, Havana, Cuba.
PHILLIPS, MELVYN D., McColl-Frontenac Oil Co., Ltd., 360 St. James St. W., Montreal, Quebec, Canada.

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CHANGES OF ADDRESS

(Old Address Follows New in Parenthesis)

DISTRICT OF COLUMBIA

BUSH, U.S.N.R. LT. CECIL D., 2817 Que St., S. E., Washington, D. C. (Esso Standard Oil Co., N. Baton Rouge, La.)
PREISER, HERMAN S., 1702 Summit Pl., N. W., Washington 9, D. C. (47 Gallatin St., N. W., Washington, D. C.)

FLORIDA

CALLAHAN, V. L., 1171 Lewis Drive, Winter Park, Florida. (Mathieson Chemical Corp., Mathieson Bldg., Baltimore 3, Md.

ILLINOIS

McNEILL, JOHN J., Goodall Rubber Co., 2050 N. Hawthorne Ave., Melrose Park, Ill. (117 West Harrison St., Chicago, Ill.
HEVERLY, L. F., 5425 Chadwick Road, Kansas City 3, Kan. (5425 Chadwick Road, Kansas City 3, Mo.)
MITCHELL, LEO S., 8228 Palm St., New Orleans, La. (306 E. Harris St., Pasadena, Tex.)

MISSOURI

GLESER, SOL M., 901 Washington Ave., St. Louis 1, Mo. (Corps of Engineers, U. S. Army, Rm. 743 U. S. Courthouse & Custom House, St. Louis 1, Mo.)

NEW JERSEY

KING, ROBERT J., Cal. Oil Co., Barber 16, N. J. (Standard Oil Co. of Cal., Materials Lab., Richmond Refinery, Richmond, Cal.)
OATES, JOHN J., Chemist, Subox, Inc., Fairmount Plant, Hackensack, N. J. (New York Testing Laboratories, 80 Washington St., New York City, N. Y.)

NEW MEXICO

PERRET, WILLIAM R., West Lab., Dept. 1111, Sandia Corp., Sandia Base, Albuquerque, N. M. (Waterways Experiment Station, P. O. Box 631, Vicksburg, Miss.)

NEW YORK

McGLOTHLIN, BRUCE B. JR., Rm. 503, Downtown Y.M.C.A., 45 W. Mohawk St., Buffalo, N. Y. (University of Cincinnati, 139 W. University St., Cincinnati 19, O.)

OHIO

ROESSING, EARL F., 211 W. Washington St., Napoleon, O. (Columbia Engineering Corp., 99 N. Front, Columbus 15, O.)

PENNSYLVANIA

ISAACKS, ALBERT N., United Engineers & Constructors, Inc., 1401 Arch St., Philadelphia 5, Penn. (P. O. Box 1293, Syracuse, N. Y.)
MacDONALD, JOHN A., University of Pittsburgh, 204 De Soto Hall, Pittsburgh 13, Penn. (University of Pittsburgh, 319 De Sota Hall, Pittsburgh 13, Penn.)
METZGER, PAUL D., 115 Tiliotson Circle, Pittsburgh 9, Penn. (Alox Corp., 3943 Buffalo Ave., Niagara Falls, N. Y.)
VIERLING, EDWARD C., JR., Pittsburgh Coke & Chemical Company, P. O. Box 1645, Pittsburgh 19, Penn. (Russell H. Coe, Pittsburgh Coke & Chemical Co., P. O. Box 1645, Pittsburgh 19, Penn.)

TEXAS

BOUDREAUX, TRACY P., 2211 Jackson St., Apt. 4, Houston, Tex. (University Trailer Village, No. 143, University of Houston, Houston 4, Tex.)
CAHILL, JOE L., 2507 Sheridan, Houston, Texas. (5006 Calhoun Road, Houston, Tex.)
JESSEN, FRANK W., 3111 Tom Green St., Austin, Tex. (1706 Westover Road, Austin, Tex.)
LINGLE, ROBERT J., Pittsburgh Coke & Chemical Co., P. O. Box 13126, Houston, Tex. (4503 Merrie Lane, Bellaire, Tex.)
ROTHROCK, E. S., Vice-Pres. and General Manager, Consolidated Chemical Industries, Inc., 640 Mellie Esperson Bldg., Houston, Tex. (General Manager, Consolidated Chemical Industries, Inc., 640 Mellie Esperson Bldg., Houston, Tex.)
STEPP, V. E., The Atlantic Refining Co., Prod. Div., P. O. Box 2819, Dallas 1, Tex. (J. H. Sullivan, The Atlantic Refining Co., Prod. Div., P. O. Box 2819, Dallas 1, Tex.)
THORNEY, CHARLES E., JR., 5205 Patrick Henry St., Bellaire, Tex. (N.A.C.E., 919 Milam Bldg., Houston 2, Tex.)
WALLACE, E. W., 5304 Huisache, Bellaire, Tex. (4428 Valerie, Bellaire, Tex.)

(Continued on Page 14)

Copies of recent issues of the Information Bulletin published by the Engineers Club of Rio de Janeiro, Brazil, have been received at Central Office NACE.

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CORROSION published in December, 1950 indices to all technical material published in the magazine from 1945 through 1950.

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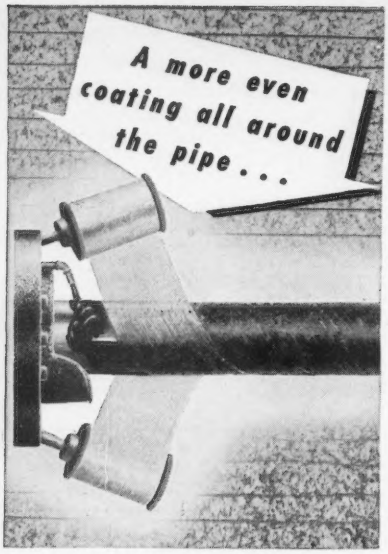

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VITRON Glass Fibers absorb no moisture; help maintain a high dielectric rating.

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(Continued from Page 12)

WATKINS, JESSE L., Shell Pipe Line Corp., 2142 Locust, Colorado, City Tex. (Shell Pipe Line Corp., P. O. Box 576, Iraan, Tex.)

UTAH

JONES, HENRY P., J. Henry Jones Co., P. O. Box 1795, Salt Lake City, Utah. (J. Henry Jones Co., 120 Apricot Ave., Salt Lake City, Utah.)

WEST VIRGINIA

WHITE, HOWARD R., 51 Oakwood Rd., Huntington, W. Va. (Tenn. Gas Transmission Co., Box 2511, Houston, Tex.)

FOREIGN

CLARK, PETER, 58, Colwyn Road, West Hartlepool, Co. Durham, England. (Anglo Iranian Oil Company, Ltd., Abadan, Iran.)

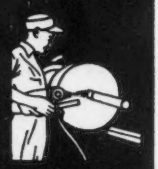
GODARD, H. P., Head of Chem. Div., Aluminium Laboratories, Ltd., P. O. Box 84, Kingston, Ontario, Canada. (Aluminum Laboratories, Ltd., P. O. Box 84, Kingston, Ontario, Canada.)

•

"Electroplating," 83/85 Udney Park Road, Teddington, Middlesex, England, has been added as an abstract sources supplying abstracts on corrosion to the NACE.

Corrosion News Deadline:
10th of Month *PRECEDING* Date of Issue

METAL SPRAYING



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Bowser, Inc.
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Paul A. Mankin, Rep.

S. D. Day Company
Houston, Texas
David W. Peake, Rep.

Houston Contracting Company
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R. P. Gregory, Rep.

Lever Brothers Company
New York, New York
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William Welch, Jr., Rep.

Mahoney Contracting Company
Lansing, Michigan
E. J. Mahoney, Jr., Rep.

Parkhill Truck Company
Tulsa, Oklahoma
Roy F. Parkhill, Rep.

R. B. Potashnick
Cape Girardeau, Missouri
R. B. Potashnick, Rep.

Rosson-Richards Company
Corpus Christi, Texas
S. L. Richards, Jr., Rep.

Transcontinental Gas Pipe Line Corp.
Houston, Texas
O. W. Wade, Rep.

The Trojan Construction Co., Inc.
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Felix M. Johnson, Rep.

Weirton Steel Company
Weirton, West Virginia
T. E. Millsop, Rep.

Worthington Pump & Machinery
Harrison, New Jersey
R. J. Allen, Rep.

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For a handling charge of $5 the National Association of Corrosion Engineers will ship postage paid to authors of technical material published in CORROSION, not earlier than six months after publication, printing plates used for figures in articles, NACE undertakes to ship such printing plates as are available, without warranty as to their condition or completeness. Those who wish to take advantage of this offer are asked to submit a request in writing, giving the issue in which the article in question was published, full address to which plates are to be shipped and billing information to:

NORMAN E. HAMNER,
Managing Editor, CORROSION,
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Houston 2, Texas

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The Metco Systems are the result of over 19 years' experience with pure zinc and aluminum coatings on many different types of structures and equipment. They provide the answer to standardization of surface preparation, coating thickness for various service conditions and after-coatings to meet specific requirements.

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Lincoln Pk. 25 (Detroit), Mich. **DIX ENGINEERING CO., INC.** 1417 Dix Road Tel. Dunkirk 1-8822	**Philadelphia 29, Pa.** **METALWELD, INC.** Fox & Hunting Park Ave. Tel. Radcliff 5-3471	**St. Louis, Missouri** **NOOTER CORPORATION** 1420 South Second Street Tel. Main 6000	**Brooklyn, N. Y.** **ARTHUR TICKLE ENGINEERING WORKS, INC.** 21 Delevan Street Tel. Main 5-4200	**Houston, Texas** **F. W. GARTNER CO.** 3805 Lamar Avenue Tel. Atwood 5338

NEW PRODUCTS – Materials – Service – Literature

Three Bulletins by The Duriron Company, Dayton 1, Ohio, have been issued and are available on request as follows: Bulletin P2—Converting Series M Durcopump to Series R. Durcopump, describes how this change may be effected at low cost. Bulletin 647—Durco Type F Teflon Lined Plug Valves, describes construction, operation and uses of this new valve. General Catalog 52—Durco Corrosion Resisting Alloys for the Chemical Process Industries also is available.

•

Cathodic Protection data can be computed on a slide rule available free from Federated Metals Division, American Smelting and Refining Company, 120 Broadway, New York 5, N. Y., on request written on company stationery by those engaged in cathodic protection work. The device provides a means of determining, with pipe size and soil resistivity known, the required magnesium anode size and life, length of pipe protected and current output.

•

A Branch of present research laboratories has been opened by Raymond C. Crippen, Consulting Chemists, Engineers and Analysts, Baltimore 2, Md., for the study of silicones. Sponsored projects are welcomed.

•

Lead Chemical Construction Bulletin No. 3, "New Developments Expand Use of Lead Construction," by Kempton H. Roll, Lead Industries Association, 420 Lexington Ave., New York 17, N. Y., a reprint from April Materials and Methods magazine is available on request from the association.

•

Model HT, a portable electric oven for processing at high temperatures (100 to 800 degrees F) operates on 110-volt circuits. Details can be obtained from Grieve-Hendry Co., Inc., 1101 N. Paulina St., Chicago 22, Ill.

•

How To Paint Follansbee Terne Metal Roofs, a bulletin of Follansbee Steel Corp., Pittsburgh 30, Pa., lists recommendations of 37 major paint manufacturers for primer and finish coats on terne roofs.

•

Incoloy, an alloy for high temperature and corrosion use has been developed by The International Nickel Co., Inc., 67 Wall St., New York 5, N. Y., for many purposes now served by the company's older alloys, which run up to 70 percent nickel. The new alloy contains about 35 percent nickel, 20 percent chromium and the balance iron and is produced in most standard rolling mill forms.

•

Alfane, a light colored synthetic resin cement, which in addition to being resistant to most acids, salts, solvents and greases, has excellent resistance to all alkalies has been developed by Atlas Mineral Products Co., Mertztown, Pa. Bulletin 5-30B gives complete details.

•

Petrobase 210, a synthetic rust preventive composition for addition to petroleum oils, petrolatums and waxes has been developed by Pennsylvania Refining Co, Butler, Pa. The material displaces water preferentially and is recommended by the manufacturer for government specification preservative oils and compounds, industrial preservative or slushing oils, household oils and water displacement fluids.

Typical physical properties are:

Color	red-brown
Spec. Gr. 60/60 deg. F	0.96/0.97
Pounds per Gal. at 60 deg. F	8.0
Visc. SSU at 100 deg. F	Approx. 3000
at 210 deg. F	100/125
Flash Pt., COC deg. F	390
Pour Pt. ASTM deg. F	25
Neutralization No.	1.0—1.5

•

Vinylite resins are used to give a nonslip, non-chipping and non-rusting coating to screw type wall coat hooks. The hooks are made by The Washburn Co., Worcester 8, Mass.

•

Physical and Chemical Properties of Agilene (Polyethylene) and Agilene Fabricated Containers describe respectively the characteristics of the resin and the kind, size and application of containers made of the material. Interested persons may secure copies from American Agile Corp., Plastics Division, 5806 Hough Ave., Cleveland 3, Ohio.

•

Solder, a 36-page book on the nature, properties and uses of solder has been published by Federated Metals Division, American Smelting and Refining Co., 120 Broadway, New York City, N. Y. The book covers thermal effects, mechanical properties, principles of soldering and fluxes, selection of solders, fusible alloys, practical applications and a resume of specifications and technical data. Copies are available on request.

•

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(Continued on Page 17)

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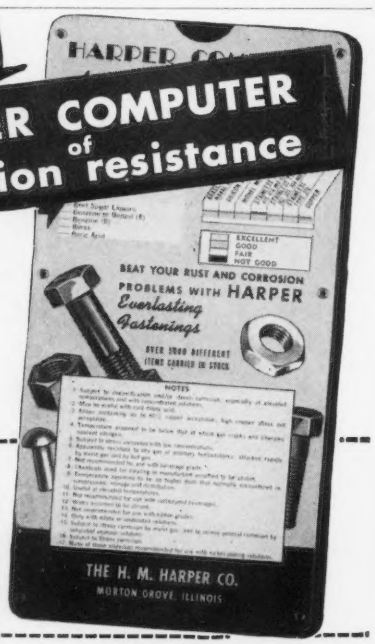

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New Products—

(Continued from Page 16)

1810 Madison Ave., Toledo, Ohio. Three times smaller than any glass fibers hitherto produced on a commercial basis, they are made by a patented process exclusive with the company. Indicated uses include filters, where it can filter particles as small as one ten-millionth of an inch, in electrical equipment and, impregnated with suitable resins, insulating tape. It has been made into glass paper on a Fourdrinier machine. Production now goes 100 percent to the armed services but commercial availability is expected in the fall of 1952.

•

An 80/20 zinc-copper alloy electrodeposited from a cyanide bath including special brightening agents has been developed by DuPont as a substitute for the undercoating of nickel customarily used for bright chromium finish. Because of the scarcity of nickel currently chromium plating was facing severe difficulties. The patented process was developed by the company's electrochemical department and reported in 1938 at the American Electroplaters' Society meeting in Milwaukee that year.

•

Vinyl manometers that can be rolled up and put in a pocket are being manufactured for field use by engineers by F. W. Dwyer Mfg. Co., 317 South Western Ave., Chicago 12, Ill.

•

A Transparent brushable or sprayable coating for polished and plated metals for use on finished products and already installed metal units in plants has been

(Continued on Page 18)

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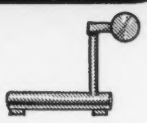

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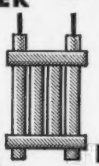

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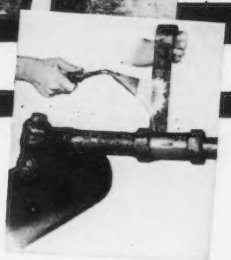

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Originators of the Coal Tar Tape for Pipe Joint Protection

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New Products—

(Continued from Page 17)

developed by Adhesives and Coatings Div., Minnesota Mining and Mfg. Co., 411 Piquette Ave., Detroit 2, Mich.

•

Anchorite 100, a phosphate compound process developed by Octagon Process, Inc., 15 Bank St., Staten Island 1, N. Y., meets specifications for a Class C (Type II) finish in U. S. Army Spec. No. 57-0-2C. Application is by immersion or spray the immersion method using five tanks. Zinc and cadmium are finished in 30 seconds to one minute, and some steel alloys require as much as five minutes. It is reported effective as a prepainting treatment on zinc, galvanized iron and cadmium.

TDC 102 gives creep stress data for rates of one percent elongation in 10,000 and 100,000 hours at temperatures from 800 to 1500 degrees F for 16 carbon, intermediate alloy and stainless metals. It is obtainable from Babcock & Wilcox Tube Co., Beaver Falls, Pa.

•

Dowell Incorporated has opened an operating station at Fourth and Terrill Streets, Beaumont, Texas. J. C. Ivy is in charge.

•

Technical Data sheets describing Classes A or B of Type II phosphate coatings for ferrous surfaces not to be painted are available from American Chemical Paint Co., Ambler, Pa. A specification chart listing characteristics of the company's phosphate coating chemicals also is available.

Pittsburgh Coke and Chemical Co., Pittsburgh, Pa., producer of pipeline enamels and protective coatings, has formed a Fine Chemical Division for production of a selected range of dyestuffs, pigments and intermediate products, pharmaceutical intermediates, textile auxiliaries and other chemicals. L. D. Barrick has been appointed head of the new division and R. H. Locke, assistant manager.

•

Users Changing from Type 302 to Type 430 stainless steels as a result of war restrictions are invited to ask for a copy of "A Guide to Type 430 Stainless Steels as Alternates of the 18-8 Series," published by Republic Steel Corp., 3100 East 45th St., Cleveland 27, Ohio. The 12-page booklet includes two pages of laboratory corrosion data on the type.

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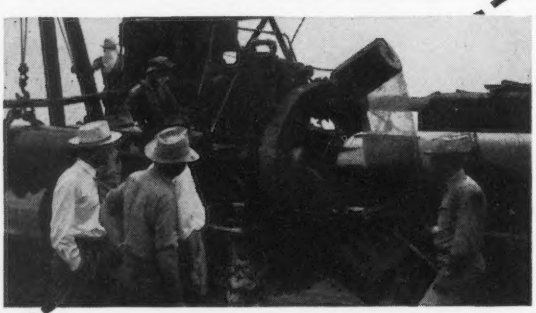

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PERSONALS

Emanuel H. Bronstein has been named Consulting Corrosion Engineer for Research and Sales Coordination by Michigan Pipe Company, Bay City, Mich. He is an NACE member.

•

S. D. Day of S. D. Day Co., Houston, leaves soon for an extended business trip to France, Spain and Sweden. Mrs. Day will accompany him, and if time permits they may also visit England. They expect to do a considerable part of their traveling by automobile.

•

Ray S. Ousterhout, formerly at Odessa, Texas, has been promoted to district sales engineer of Dowell Incorporated's Midland, Texas, office. **Clay Courter** replaces Ousterhout at Odessa and **Warren Salee** moves to Hobbs, N. Mex., replacing Courter.

•

H. C. Milton has been appointed assistant district sales manager for American Cyanamid's Industrial Chemical Division at Boston, Mass.

•

Henry L. Howard, formerly a welding engineer with Goodyear Aircraft Company and Republic Steel Company has been named manager of the Houston, Texas, branch office opened at 5815 Clinton Drive, Houston, by Wall Colmonoy Corp.

•

Edison C. Sickman, formerly sales coordinator has been appointed general sales manager of Atlas Mineral Products Co., Mertztown, Pa. **Earl A. Erich** will be in charge of technical service activities.

•

Maj. Gen. R. C. Coupland (USAF Retired) has been appointed manager of the Product Development Department of Koppers Company's Metal Products Division.

•

Charles L. Kepley has been appointed chemical field engineer for A. & P. Finishing & Mfg. Co., Melvindale, Mich. Mr. Kepley is an NACE member.

•

C. S. White has been appointed manager of Dearborn Chemical Company's Eastern Division with headquarters in New York. He replaces Herbert J. Cornell who died July 13 after 46 years of continuous service with the company.

Corrosion Abstracts

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Vol. 7 September, 1951 No. 9

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*** PAGINATION OF CORROSION ABSTRACTS**

Two numbers appear on each page of Corrosion Abstracts. The number in the upper outer corner is for page sequence within the issue only. The number in the lower outer corner, which is followed by the letter "a," denoting "abstracts," is for the convenience of those who bind Corrosion Abstracts by volumes. Because both numbers appear on each page and because it is believed indexing by the volume serial number will be more useful, the "Index to Corrosion Abstracts" is keyed to the number in the lower outer corner of each page followed by the letter "a."

GENERAL

• Miscellaneous

1.1

Draft German Specification DIN 50900: Corrosion of Metals. (In German.) Deutsche Normenausschuss. *Werkstoffe u. Korrosion,* **1,** No. 3, 112-115 (1950) Mar.; *Z. Metallkunde,* **41,** No. 3, 91-94 (1950) Mar.

A list of definitions of German terms relating to corrosion (electrochemical theory, types of corrosion, and testing) which may be useful to the English reader. Comments by G. Schikorr on pp. 110-111.—BNF.

1.1

Theory of Corrosion for Engineers. W. L. Orr and H. A. Stafford, Univ. of Southern Calif. *J. Chem. Education,* **27,** No. 4, 202-208 (1950) Apr.

Discussion gives engineering students a brief survey of the theory of corrosion and its application intermediate between the two extremes. This includes electrochemical theory of corrosion, factors influencing corrosion and methods of controlling corrosion. 11 references.—INCO.

1.1

Corrosion and the Final Choice—Additional Factors In Metal Selection. W. D. Mogerman and F. L. LaQue, INCO. Chapter V in Nickel, Monel, and Inconel—Their Contributions to Chemical Engineering. *INCO Publication,* 11 pp. (1949) Nov.

Factors in metal selection include availability in required forms, amenability to fabrication by standard methods, ability to withstand physical stresses of normal service resistance to corrosion, effects on the product and the real cost of equipment. Factors in corrosion that are often overlooked are also included. —INCO.

1.1

The Study of Corrosion in the (U.S.) Colleges. Hugh J. McDonald. *Corrosion,* **5,** No. 10, 326-329 (1949).

A brief review is presented of the type of corrosion work being carried out in various U. S. institutions.—MA.

1.1

New Techniques in Chemical Literature. *Ind. Eng. Chem.,* **42,** 1456-1468 (1950) Aug.

Symposium consists of the following papers presented at 116th ACS meeting, Atlantic City, Sept. 1949: "Conventional and Mechanized Search Methods," S. W. Cochran and J. W. Perry; "Punched Card Code for General Organic Research," Kenneth N. Campbell and Barbara K. Campbell; "Microfilm Selection Equipment in Information Work," H. T. Engstrom; "High-Speed Electronic Computing Devices," Jay W. Forrester; "Microcards, a New Form of Publication," Fremond Rider; "Microcards and Microfilm for a Central Reference File," J. W. Kuipers; and "Problems in the Use of Microfilms, Microprint, and Microcards in Research Libraries," Maurice F. Tauber.—BLR.

PRIMARY SOURCES OF ABSTRACTS PUBLISHED IN CORROSION

AER—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Onatrio, Canada.

AWWA—Journal, American Water Works Association. Amer. Water Works Assoc., 500 5th Ave., New York 18, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BLR—Battelle Library Review, Battelle Memorial Institute Library. 505 King Ave., Columbus, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EL—Electroplating. 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum. 26 Portland Place, London W#1, England.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italiana. Associazone Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RA—Refrigeration Abstracts, American Society of Refrigeration Engineers. 40 West 40th St., New York 18, N. Y.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

TDD—Technical Data Digest, Air Material Command—Technical Service Section, Central Air Documents Office, Wright-Patterson Air Force Base, Dayton, Ohio.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

1.1

The National Association of Corrosion Engineers, Its Aims and Role in the Development of Experience in Combating Corrosion Problems. F. L. LaQue. *Corrosion*, **6**, No. 3, 88-91 (1950) Mar.—BNF.

1.1

Suggestions for the Preparation of Technical Papers. Robert T. Hanlett. Proceedings of the I.R.E., 38, 228-233 (1950) Mar. *Sperry Eng. Rev.* (1949) May-June.

Value and purpose of technical papers is discussed followed by general suggestions for their preparation. Separate sections deal with introduction, main body, and conclusion.—BLR.

1.1, 6.4

Metallic Corrosion. S. C. Churchill. *Pract. Eng.*, **20**, No. 499, 181-182 (1949).

A simple explanation of the causes of corrosion is attempted, and some methods of its prevention in the case of metals such as aluminum, magnesium, etc., are described.—MA.

• Importance

1.2

Lead Contamination: From a Metallurgist's Notebook. H. H. Symonds. *Met. Ind.*, **76**, 405-406 (1950) May 19.

Whisky was found to contain a lethal quantity of lead. Tests were carried out on the whisky as received and on the residue found after it had been left standing in a copper flask. It was concluded that the lead was picked up from the solder in the seams and the tin coating of the inside of the flask.—BLR.

Sources of

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CORROSION ABSTRACTS

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CARNEGIE LIBRARY OF PITTSBURGH, 4400 Forbes St., Pittsburgh 13, Pa.

NEW YORK PUBLIC LIBRARY, New York City.

U. S. DEPT. OF AGRICULTURE LIBRARY, Office of Librarian, Washington, D. C. (Special forms must be secured).

Persons who wish to secure copies of articles when original sources are unavailable, may apply directly to any of the above for copies. Full reference information should accompany request. The National Association of Corrosion Engineers offers no warranty of any nature concerning these sources, and publishes the names for information only.

NACE will NOT accept orders for photoprint or microfilm copies of material not published by the association.

• Reviews

1.3, 7.1, 2.3

Excerpts from Symposium on Testing Gear Oils. *SAE Journal*, **58**, 46-53 (1950) Apr.

Based on "Performance Testing of Gear Lubricants," by W. J. Backoff, N. D. Williams and K. Boldt; "Laboratory Wear Tests With Automotive Gear Lubricants," S. A. McKee and others; and Moisture Corrosion Test for 2-105B Gear Lubricants," by T. P. Sands.

Includes illustrations of equipment, graphs of corrosion-test data; and discussion of Sands' paper by J. P. Stewart.—BLR.

1.3, 3.8, 3.5

Review of "Forum on Corrosion Research" held at Washington, D. C., Nov. 9-10, 1949. J. J. Harwood and F. Schulman. *J. Electrochem. Soc.*, **97**, 83C-91C (1950) Apr.

Papers by various authors on electrochemical fundamentals, passivity and inhibitor studies, corrosion mechanisms and kinetics and high temperature corrosion studies are reviewed.

1.3, 4.1

Experience of the Study of Corrosion Problems in the U.S.A. (in 1947). (In Swedish.) Per-Ake Wallgren. *IVA*, **21**, No. 1, 36-41 (1950).

A general review of corrosion research in progress in 1947 in the U.S.A. is followed by more detailed consideration of corrosive atmospheres and of work on underwater corrosion. 28 references.—MA.

1.3

Fundamentals of Corrosion: Forms in Which Corrosion Occurs: Theories of Corrosion and Means of Prevention. W. Machu. *Werkstoffe u. Korrosion*, **1**, 265-277 (1950) June-July.

Good review dealing with commercial significance of corrosion problem, causes of corrosion, erosion, cavitation, corrosion with evolution of hydrogen, local elements, part played by oxygen in corrosion, electromechanical theory of corrosion, pitting (illustration of this form of attack in a nickel-silver watch case), protective skins and passivity, intercrystalline corrosion, corrosion-fatigue, kinetics of corrosion and protective measures.—INCO.

1.3, 6.3

Anglo-American Literature on Titanium and Zirconium Published in 1949. O. Kubaschewski. *Z. Metallkunde*, **40**, No. 12, 460-462 (1949).

A brief review, with 24 references.—MA.

1.3, 5.4

The Paint Industry in Germany During the Period 1939-45. N. R. Fisk and H. W. Bowron. BIOS Surveys Report No. 22, HMSO 1950.

Like other reports in this series (formerly called Overall Reports) this survey is a collation of all reports on German Industry covering a particular field, and includes many references. The manufacture and uses of zinc oxide and lithopone have been dealt with at much greater length in BIOS Final Reports No. 1401 and 1140 respectively, but mention is made here of the use of zinc oxide in ships bottom paints and of lithopone in water paints. Zinc chromate was used as a primer for light alloys, and various zinc soaps were used in antifouling paints. It is reported that successful emulsion paints were made using zinc ammonium alginate and that "Soligen" driers contained zinc napthenates. Sections are also devoted to the manufacture of cadmium pigments, including cadmium lithopone, and to luminous and radioactive pigments.—ZDA.

1.3

Annual Reports, Soc. of Chem. Ind. J. C. Chaston. *Progress of Applied Chem.*, **33**, 143-144 (1948).

A review with 108 refs.—RPI.

• Bibliographies

1.4, 6.2

Nodular Iron—A Bibliography. F. R. Morral, Syracuse Univ. *Am. Foundryman*, **18**, No. 1, 61-64 (1950) July.

The bibliography is complete up to Jan. 1950.—INCO.

1.4, 2.4

Bibliography, Supersonic or Ultrasonic, 1926 to 1949. Beth Curry and Eugene Hsi, compilers. 152 pages. 1949. Oklahoma Agricultural and Mechanical College, Research Foundation, Stillwater, Okla.—BLR.

1.4, 8.5

The Corrosion and Lining of Sulphate Digesters. T. T. Collins, Jr. *Paper Trade J.*, **130**, 32-34+; 20-22 (1950) May 25, June 1.

Bibliography includes detailed abstracts of papers on the above topic published through 1949.—BLR.

• Directories of Materials

1.5

The Corrosion Forum: Materials Selection Chart. M. M. Hoover. *Chem. Eng.*, **57**, No. 8, **197-200** (1950) Aug.

Materials to be used for the most satisfactory resistance to corrosion from a long list of chemicals are listed in a four-page tabulation.

• Packaging

1.6, 3.6

Thermodynamics of Dilute Aqueous Solutions, with Applications to Electro-Chemistry and Corrosion. M. J. N. Pourbaix. Translated by J. N. Agar. Foreword by U. R. Evans. Med. 8vo. Pp. xv + 136, with 27 illustrations. 1949. London: Edward Arnold and Co.

Many who are concerned with the study of metallic corrosion still maintain that the thermodynamical line of approach to corrosion problems gives little practical guidance towards their elucidation, but in recent years the value of the thermodynamical method of treatment has been established beyond all doubt. Dr. Pourbaix has added greatly to the value of the thermodynamical method of approach to the study of corrosion in dilute aqueous solutions by developing graphical means of representing corrosion changes. By plotting the pH of an aqueous solution against the equilibrium potential of the metal in contact with it, he obtains a chart which depicts the domains where corrosion, passivity and cathodic protection may be expected to occur. Such graphical diagrams con-

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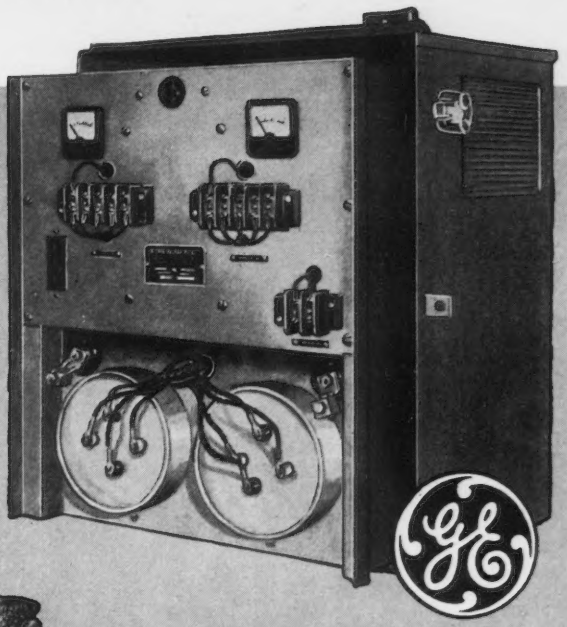
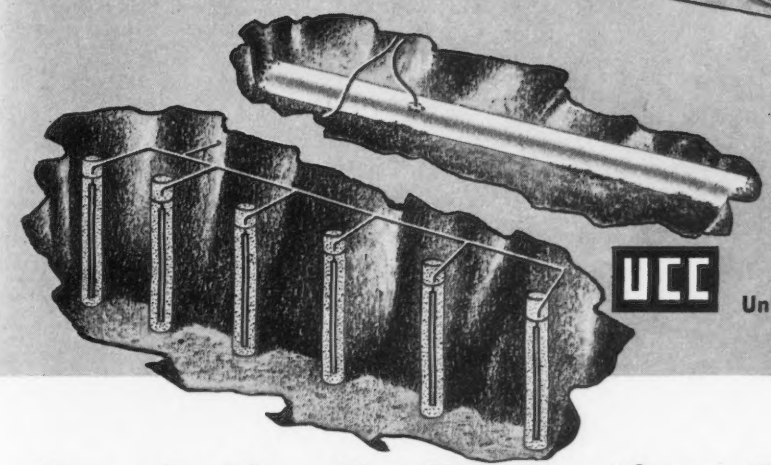


GENERAL ELECTRIC



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187a

tain much information of value to the corrosion chemist. They clearly show the conditions under which given oxidation and reduction reactions are possible from the energetic viewpoint and enable the results of experimental observation to be predicted and interpreted. The equilibria covered in detail include those between copper, iron, chromium and nitrogen respectively in contact with dilute aqueous solutions.

The novelty of Dr. Pourbaix's work and the simplicity of the procedure he has devised should make a special appeal, and no one who is concerned with corrosion problems can afford to be without this book. It is excellently written, and the translator has taken a considerable amount of trouble in presenting the author's work in an accurate and readable form. This is particularly noticeable in the third chapter, where the laws of chemical and electrochemical equilibrium are explained in a most lucid manner. From every aspect the book can be strongly recommended.—MA.

1.6, 6.5, 2.4

Materials Engineering of Metal Products. N. E. Woldman. 583 pp., 1949. Reinhold Publishing Corp., New York.

Presents the materials used in various types of industries and different applications in an attempt to correlate the metallurgy with engineering design and service applications. Sections on materials for lightweight construction (aluminum alloys, magnesium alloys, high-strength low alloy and stainless steels); for mechanical products (gears, springs, bearings, threaded products); for electrical industries (magnetic materials, electrical contacts, thermostat metals, resistance alloys); for special and severe service (corrosion, highly corrosion-resistant materials, dealing mainly with high-nickel alloys and stainless steels; high-temperature materials); testing (mechanical and non-destructive). An appendix contains a large number of useful tables.—MA.

1.6, 2.3

Metallurgical Applications of the Electron Microscope. Symposium, London, November, 1949. Inst. Metals Monograph Rep. Ser. No. 8. Demy 8vo. vi + 164. Illustrated. London (1950). The Institute, 4 Grosvenor Gardens, S.W.1. $3.50, post free; $2.00, to members of the Institute.

Contents: N. P. Allen, "The Application of the Electron Microscope in Metallography"; Pierre Grivet, "Electron Microscopy in Metallurgy"; H. Mahl, "The Use of the Electron Microscope in Metallurgical Research in Germany During and Since the War"; G. L. J. Bailey and Sheila Vernon-Smith, "The Structure of Some Non-Ferrous Alloys as Revealed by the Electron Microscope"; J. Nutting and V. E. Cosslett, "A Replica Technique for the Examination of Fracture Surfaces with the Electron Microscope"; J. Nutting and V. E. Cosslett, "The Dry Stripping of Formvar Replicas from Etched Metal Surfaces"; J. Trotter, D. McLean, and C. J. B. Clews, "The Microstructure of a Water-Quenched Carburized Iron"; Fred Keller, "Electron Microscopy of Light-Metal Alloys"; G. L. Bucknell and G. A. Geach, "Observations on the Age-Hardening Process in an Aluminum-Copper Alloy"; Arthur F. Brown, "Elementary Slip Processes in Aluminium as Shown by the Electron Microscope"; B. S. Cooper and G. A. Bassett, "Studies in the Electron Microscopy of Nickel-Chromium Alloys"; J. I. Morley, "A Note on the Examination of Metal Powders by the Electron Microscope"; C. M. Schwartz, "The Progress of Electron Microscopy of Metals in America (Excluding the Light Metals)."—MA.

1.6, 2.3

The Practice of Electron Microscopy. Edited by D. G. Drummond. *J. Roy. Microscop. Soc.* (iii), **70,** No. 1. Cr. 4to. 141 pp. illustrated. (1950) London: The Royal Microscopical Society, B.M.A. House, Tavistock Square, W.C. 1.

All investigators having anything to do with electrom microscopy will be indebted to Dr. Drummond, who, with the assistance of a large number of other practical microscopists, has collected nearly all known techniques in biology, chemistry, metallurgy and so on into one short volume. In this he has performed a truly remarkable feat of editing for the style of the whole volume is uniform and uniformly high. Copious references are given, but the reader will be excused if he fails to look them up because the various techniques are described by Dr. Drummond with a clarity seldom attained in the original papers. Newcomers to electron microscopy will be specially pleased to find that so many of the snags, which apparently did not trouble the originators of the techniques, have been anticipated for them by the authors of this collection. The only criticism which can be made is that it is still necessary to read between the lines for condemnation of bad or unnecessarily complicated techniques. In particular, while it is no doubt correct to describe some twenty replica methods for metals, it should be stressed that one—the plastic-replica method—is adequate for 95 percent of metallurgical specimens and rather more guidance should have been given as to when the more difficult techniques are necessary.

However, it is not only practical microscopists who should have this book by them, for an acquaintance with the techniques involved is essential to all who wish to cultivate a proper critical attitude to scientific results obtained with the aid of the electron microscope. For example, it may come as a surprise to many to find that it is difficult to obtain figures for magnification with even 10 percent accuracy.—MA.

• Organized Studies

1.7, 5.3

Report on the Work of the Tin Research Institute, 1949. Tin Research Institute, 16 pages (1950).

Reports work on tinplate, hot-tinning, bearing metals, bronze, solder, electrotinning, tin-zinc and tin-lead coatings, speculum plate, other tin-alloy coatings, and on corrosion. Includes data on staff, committees, publications, exhibitions, etc.—BLR.

1.7, 3.4

The Identification of Solid Corrosion Products. C. M. Schwartz. *Corrosion,* **6,** No. 2, p. xi. (1950) Feb.

Program of NACE Technical Practices Committee TP-11, on Identification of Corrosion Products.—MR.

1.7, 3.2, 6.3, 4.6

Copper Water Pipes; Result of BNFMRA Investigation on Corrosion. *Met. Ind.,* **76,** 129-130 (1950) Feb. 17.

Cause of occasional pitting of the above was traced to carbonaceous films produced on the pipes during the manufacturing operation. Occurrence of these films can easily be prevented and the pitting thus avoided.—BLR.

1.7, 3.6, 4.5

A Co-Operative Approach to Electrolysis Problems. Russell M. Lawall. *Corrosion,* **5,** No. 3, 79-84+ (1949).

The activities of a Detroit committee formed to study stray-current corrosion underground are described. The article deals mainly with corrosion of ferrous metals, but non-ferrous metals are briefly mentioned.—MA.

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1.7, 2.3, 7.1, 3.5

Coal-Ash Corrosion of Metals at Elevated Temperatures. C. T. Evans, Jr., Elliott Co. Paper before ASTM, 53rd Ann. Mtg., Atlantic City, June 26-30, ASTM, 1950, Preprint No. 55, 6 pp.

A cooperative study with the Locomotive Development Committee of the Bituminous Coal Research Association and the Crucible Steel Co. of America was conducted with S-588 (20.31 nickel-18.38 chromium - 4.69 columbium - 4.18 molybdenum-3.08 wolfram-1.50 manganese) heat-resisting alloy at 1350 degrees F. In order to observe the possible stress-corrosion effects of coal ash on this material, stress-rupture tests of specimens in contact with raw coal ash from representative Illinois coal and specimens coated with separated Illinois coal ash were compared with blank specimens. In addition to S-588, several other metals, including Types 430 and 446, 19-9 DL, Inconel, nickel-155, aluminum bronze and Timken 16-25-6, of interest to the builders of gas turbines for locomotive service were also tested in unstressed condition at 100, 135 and 150 degrees F in contact with representative Ohio coal ash. In these tests, specimens cut from flat sheet or bar stock were grouped in casserole with only about one-half of the specimens underneath the ash.—INCO.

• Fundamentals

1.8, 6.5

Metallic Materials of Electrotechnics. (In German.) A. Schulze. Metallische Werkstoffe der Elektrotechnik. 1949, 403 pp. Published by Metall-Verlag G.m.b.H., Berlin W 15. £2 10s.

The first section of this German book deals with conductor materials (copper and alloys, aluminum and alloys, zinc and alloys, iron 53 pp). Section two deals with metallic resistance materials (pp 54-243): this longest section of the book is a reprint with some extensions and additions of the author's earlier book, Metallische Elektrische Werkstoffe, published 1941. The third section covers metallic materials for thermoelements (pp 244-356). A bibliography of nearly 400 references is provided and a subject index. The paper and binding are poor.—BNF.

TESTING

• General

2.1, 2.3

The Choice and Interpretation of Corrosion Tests. G. T. Colegate. *Sheet Met. Ind.*, **27**, No. 275, 259-266 (1950) Mar.

Corrosion tests are discussed under the following headings: Total immersion, alternate-immersion, atmospheric exposure, salt-spray, galvanic corrosion, anodic and tess ton metallic coatings. The limitations of laboratory tests are poinetd out and emphasis laid on the importance of choosing correctly both the type of test used and the method of assessing the corrosion damage.—BNF.

2.1, 5.4

Discussion of Paper on Visual Rating of Rusted Steel Specimens. H. L. Faigen and J. C. Hudson. *ASTM Bull.*, No. 162, 67-69 (1950); cf. *Review*, **1949**, 170.

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painted steel specimens than that proposed in the original paper is given and discussed.—RPI.

2.1

Graphical Method of Simultaneously Determining the Optical Constants and the Thickness of Thin Metallic Films. (In French.) D. Male. *Comptes Rendus,* **230,** No. 14, 1349-1351 (1950) Apr. 3.

Brief description of a method of calculation from measurements of transmission and reflection of light by thin metallic films, 10^{-7} to 10^{-5} cm thick, on glass; examples for gold and silver.—BNF.

2.1, 3.8

New Pointers in the Study of Metallic Corrosion in the Systems Me/MeX/X, by Measuring an Electrical Effect in a Magnetic Field. (In Italian.) U. Croatto. Assoc. Ital. Met., 2nd National Congress, May, 1948; Papers on Corrosion, pp. 1-7.

Considers the mechanism of corrosion of a metal by a non-metal (e.g. of lead by sulfur) in which a layer of a semiconducting compound is formed between the two; measurement of the Hall effect (current induced in the presence of a magnetic field) in this layer gives information on the process of corrosion and provides the basis for a quantitative study.—BNF.

• On Location Tests

2.2, 8.10, 5.3

Corrosion in Sulfur Production; The Use of an Alloy Protective Coating. Norman Hackerman and D. A. Shock. *Corrosion* (Technical Section), **6,** No. 6, 195-200 (1950) June.

Describes apparatus devised and installed in the field which permitted measurements of the rates of corrosion during the various phases of the above. Severe corrosion occurred only when water and molten sulfur were in contact with the steel surfaces together. Coatings containing zinc, magnesium and aluminum were found to be uniformly more corrosion resistant than galvanizing alone. —BLR.

2.2, 5.4, 4.2, 5.9

Protection of Iron Against Atmospheric Corrosion by Means of Paint. Corrosie Commissie IV. CIMO, Afd. Corr., Circ. No. 26, 58 pp. (1949).

Results of outdoor exposure tests which have been in progress for 6-11 years are reported. Panels were bent at 45° so that inclined and horizontal surfaces were exposed; where primers only were tested, corrosion was most severe on the horizontal underside; with coated iron oxide primers the horizontal underside was the least attacked; with coated red lead primers there was little difference in the surfaces. The rate of corrosion at different test stations was related to the conductivity of the rain water collected, but no influence of specific ions could be detected. Pretreatment by sandblasting or pickling greatly improved performance, but there was no marked difference between the two procedures nor between different methods of pickling. While uncoated red-lead primers give better results when prepared with raw linseed oil than with various bodied oils, there was little difference with coated primers, the determining factor being the thickness of the priming coat. Up to 10 percent of the red lead could be substituted by whiting or asbestine and 10-50 percent by iron-oxide without deterioration, but 10 percent of graphite was deleterious. Iron oxide primers were inferior to red-lead primers, but were improved with bodied oil media or by the addition of 10-20 percent of zinc oxide. The various finishing paints used, which were based on white-lead, zinc oxide, white lead/zinc oxide, lead titanate or aluminum, were about equal in performance. Experiments on the use of thin (15 microns) coats of primers as a means of accelerating the tests are in progress.—MA.

2.2, 6.4

Tidewater Exposure Tests on Magnesium Panel Surfaces Treated by the Consolidated Vultee Corp. I. M. Weiss. PB. 9823, Frames 39; Board of Trade, Ger. Div., ORR. 42/50.

Comparative data are given on the corrosion resistance of magnesium base alloys when exposed to tidewater afer 3 different pretreatments. The panels were protected by various paint systems.—RPI.

2.2, 6.6

Outdoor Weather Aging of Plastics Under Various Climatological Conditions. S. E. Yustein and R. R. Winans, NY Naval Shipyard, & H. J. Stark, Bu. Ships. Paper before ASTM, 53rd Ann. Mtg, Atlantic City, June 26-30, 1950. ASTM, Preprint No. 114, 13 pp. (1950).

Effects of outdoor weather aging under widely different climates are investigated for various types of plastic materials. Fire climatological regions are represented in the program which provides for outdoor exposures on sites located in Panama Canal Zone, New Mexico, New York Naval Shipyards, Fort Churchill, Manitoba, and Point Barrow. The report covers exposures for 1, 3, 7, and 12 months. The materials dealt with in this report include five types of clear transparent sheet plastics, six types of laminated materials and five types of molded terminal bars. The sheet materials are evaluated after each period of exposure for tensile and flexural properties, hardness, and dielectric constant and power factor. The transparent materials are evaluated also for light transmission and haze. The molded terminal bars are evaluated for insulation resistance, dielectric strength and high impact shock resistance. Six-month and one-year exposure produced some changes in the properties evaluated, but these changes were, on the whole not sufficient to affect seriously the serviceability of the samples tested. Differences in the effects observed varied but slightly with the different climatic conditions.—INCO.

2.2, 3.6, 8.4

Results of Galvanic Corrosion Tests Involving 9% and 5% Nickel Steel Tubing Coupled to N-80 Casing. *Corrosion* (News Section), **6,** 1 (1950) July.—BLR.

Briefly described.—BLR.

2.2

Exposure and Corrosion Tests. W. M. Pierce, chairman, Report of Committee B-6 on Die-Cast Metals and Alloys, Subcommittee V, American Society for Testing Materials, Preprint No. 12, 1950.

The results of the 10-year testing of magnesium-base and zinc base alloys from five outdoor (Key West, Fla.; Sandy Hook, N. J.; New York, N. Y.; Altoona, Pa. and State College, Pa.) and three indoor sites (Coco Solo, C.Z.; New Kensington, Pa. and Tuscon, Ariz.) after 10 years of exposure are tabulated. The remaining lot of magnesium-base and zinc-base alloy specimens will be left at these eight sites until 1959 for a total exposure of 20 years.—GPC.

• Laboratory Methods and Tests

2.3, 5.4

Technical Development in the Building Industry. A. Meunier. *Trav. Peint,* **5,** No. 4, 183-186 (1950).

The development of new types of paint for interior and exterior decoration is traced historically. Accelerated weathering tests are discussed.—RPI.

2.3

Nephelometric Testing. (In Italian.) G. Potracchi. *Met. Ital.,* **42,** 58-59 (1950) Feb.

Discusses the appearace of turbidity when ferrous materials are immersed in a clear liquid. Describes results of some experiments which indicate that degree of turbidity is an indicator of corrosion resistance, also of corrodibility vs. variation of internal energy due to magnetization and mechanical stressing.—BLR.

2.3, 5.5, 6.6

Resistance of Concrete and Protective Coatings to Forces of Cavitation. W. H. Price, G. B. Wallace. *J. Amer. Concr. Inst.,* **21,** No. 2, 109-120 (1949) Oct. *Applied Mechanics Rev.,* **3,** No. 7, 205 (1950) July.

A machine used for producing cavitation erosion in the laboratory is described and the results of tests made to investigate the effect of mix proportions, surface treatment and protective coatings on the resistance of concrete to cavitation are discussed. Through proper use the resistance of concrete surfaces to cavitation erosion is extended 3 or 4 times. Heavy rubber coatings bonded well to the surface of the concrete have proved effective.—INCO.

2.3

Detection of Surface Films by Means of Electron Interference. H. Raether. *Z. Naturforsch.,* (Germany), **40,** 582-587 (1949) Nov. *Metals Rev.,* **23,** No. 3, 42 (1950) Mar.

Experiments with zinc and aluminum were made to show that the possibility of detecting surface films—and of measuring their thicknesses with a fair degree of accuracy—depends upon the surface smoothness of the metals.—GPC.

2.3, 6.4, 3.2

The Structure of Electrolytically Polished Aluminum Surfaces and Their Oxidation. (La structure des surfaces d'aluminium polies electrolytiquement et leur oxydation.) H. Raether. *Metaux & Corrosion* (France), **25,** No. 293, 1-8 (1950) Jan.

Electrolytically polished monocrystals of aluminum were studied by means of electron diffraction and results compared with those obtained by solution potential measurement. The freshly polished surfaces were cleared of alumina films of variable thicknesses by a polishing bath; a perchloric-acetic bath gave the cleanest surface as illustrated by an electron diagram of an aluminum monocrystal. A maximum thickness for the oxide layer is given as 10 Å. The surface polished in an phospho-chromic bath showed a considerable continuous depth which indicates an oxide layer thickness

of 50-80 Å. An alumina film sufficiently thick to hide aluminum interference (> 60-80 Å), recovers the polished surface in a perchloric-methanol bath. The solution potential measurement of a surface is much more negative because the surface is cleaner, as shown by the potential of a specimen freshly polished in a perchloric bath which is more negative (—1180 mv) than that of a surface freshly polished in a phospho-chromic bath (—760 mv). Exposure to air of an aluminum surface polished in a perchloric bath makes the oxide layer grow, which is illustrated in an electron diagram by a growth of continuous depth which does not obscure completely, even after a month's exposure, the interferences of aluminum. The solution potential varies from —1200 mv to —760 mv during exposure of the specimen to air and becomes fixed at the end of 10 days at a value of —760 mv. 22 references.—ALL.

2.3

Simple Apparatus for Salt-Spray Corrosion Tests. E. Recchia. *Ind. della Vernice,* **3,** No. 32, 242-4 (1949).

A 10-1 liter glass bottle, with the base cut off and replaced by a sheet of plastic to form a non-hermetic seal, serves as the chamber. The bottle is inverted and the mouth closed by a rubber bung through which passes the atomizer. The panels are supported in the upper half and the salt solution, the level of which is controlled manometrically, is in the lower half.—RPI.

2.3, 6.7

Durability Tests of Metalite Sandwich Construction. David G. Reid. *ASTM Bull.,* **1950,** Feb. 28-31.

Above material consists basically of a relatively thick, end grain, balsa core to which are bonded thin facings of high-strength aluminum alloy. Effects of accelerated exposure of edge-protected and unprotected specimens to atmospheric and salt-spray on weight change, tensile strength and fatigue strength were determined.—BLR.

2.3

Accelerated-Cavitation Research. W. J. Rheingans. *Trans. ASME,* **72,** 705-724 (1950) July.

Cavitation-pitting tests described were made with an accelerated-cavitation machine of the vibratory type. An attempt was made to solve some of the phenomena of cavitation by varying amplitude of vibration, depth of submergence of the test specimen and by using alkalies, acids and oils as test liquids. Other tests were made to determine relative resistance to pitting of recently developed materials. Miscellaneous ferrous and nonferrous metals and alloys, sprayed metals, also non-metallic materials (Thiokol rubber on a stainless-steel base), were tested. Data are tabulated and graphed. Exposed specimens are illustrated. 12 ref.—BLR.

2.3

Corrosion Testing. R. N. Ride. *Plating Notes,* **2,** 44-65 (1950) Apr.

Discusses corrosion and corrosion resistance, the electrochemical theory of corrosion, general principles of corrosion testing and various types of corrosion tests. Some new types of test equipment are described and illustrated. 15 ref.—BLR.

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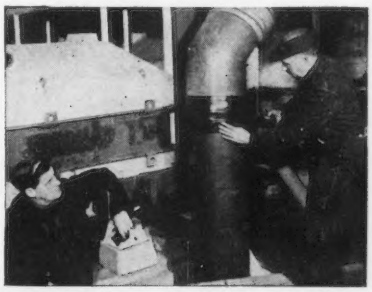

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2.3, 3.2

Testing Corrosion-Resisting Steels for Intergranular Corrosion. H. J. Rocha. *Stahl u. Eisen*, **70**, 608-609 (1950) July 6.

Review and evaluation of methods proposed for intergranular-corrosion testing in weldments. Advantages and techniques of application of copper sulfate-sulfuric acid method receive special attention.—INCO.

2.3, 7.1

Moisture Corrosion Test for 2-105B Gear Lubricants. T. P. Sands, Monsanto Chem. Co. Paper before SAE Nat. Fuels & Lubricants Mtg., St. Louis, Nov. 4, 1949. *SAE J.*, **58**, No. 47, 50-53 (1950) Apr.

The Almen Pin Moisture Corrosion Test was carried out to determine whether absolute or relative humidity was the significant variable in the test and what the effect is of varying oil temperature. The details of the test are given. It was found that the absolute humidity must be constant to maintain accuracy of the test. The gear oil which allows only a comparatively low temperature rise is less severe on rusting. Charts.—INCO.

2.3

Polarographic Analysis in Metallurgy. (In Italian.) Giovanni Semerano. *Met. Ital.*, **42**, 121-128 (1950) Apr.

Describes the method in general. Reviews the various quantitative methods, with special attention to recently developed one, giving limits of precision and applicability. Describes various cases for which polarography has been shown to be particualrly suited: analysis of metals and alloys; analysis of protective coatings; and study of corrosion. 101 references.—BLR.

2.3

Radioisotopes Aid Corrosion Research. J. M. Swartout. *Petro. Eng.*, **22**, No. 4, C31-C32 (1950) Apr.

Investigations at Corrosion Research Laboratory, Univ. of Texas, are of a fundamental nature, but the main study is of minute differences on the surface of metals. Dr. N. Hackerman believes that radioisotopes may enable him to locate sensitive spots on metallic surfaces and to determine the effects of certain salts in decreasing the resistance to corrosion. Carbon 14 and Chlorine 36 are in use, radio-sulfur was experimented with and a radioisotope of chromium is expected to be used.—INCO.

2.3

Utilization of Electron Microscope and Infrared Spectrophotometer for the Examination and Testing of Materials. S. A. Szaqlewicz, U. S. Naval Air Material Center. Report AML NAM AE 424526, Part 1 (Aug. 1949); *Prev. Deterioration Abst.*, **8**, No. 1: Met. 1, A-790 (1950).

The identification of thin corrosion films on metal specimens by using the electron diffraction adapter of the electron microscope and infrared spectrophotometer are discussed in detail. Sample preparations are described in the abstract.

2.3, 6.4

The Fundamentals of Corrosion of Metals Under Stress. Part I — Aluminium. P. F. Thompson. Aeronautical Res. Labs., Australia, Report S.M. 143, 26 pp. (1950) Jan. Obtainable from Aeronautical Research Laboratories, Fishermen's Bend, Melbourne.

Potential/time curves on stressed and unstressed commercial purity aluminum were determined in distilled and tap water and salt solutions. No appreciable difference in potential was found between stressed and unstressed material except when the stress was sufficient to rupture the oxide film.—BNF.

2.3, 3.6

Potentials of Certain Metallic Sulfides and Mixtures. (In Russian.) B. Z. Ustinskii and D. M. Chizhikov. *J. Applied Chem.*, USSR, **22**, 1249-1252 (1949) Dec.

Potentials of copper, nickel and cobalt sulfides and mixtures of the sulfides of copper and nickel in sulfuric acid solution and in solutions of the corresponding sulfates were measured. Results are tabulated, charted and discussed.—BLR.

2.3

Polarographic Study of Corrosion Phenomena. P. Van Rysselberghe and others. *Corrosion*, **6**, No. 3, 105-113 (1950) Mar.

This is reprinted from Corrosion and Material Protection, March/April, 5, No. 2, 11-16 (1948).—BNF.

2.3, 3.5

Corrosion Fatigue — The Influence of Disarrayed Metal. D. Whitwam and U. R. Evans. *J. Iron Steel Inst.*, **165**, 72-79 (1950) May; Reprinted *Corrosion*, **7**, No. 1, 28-40 (1951) Jan.

Experiments were conducted to determine whether a preliminary period of dry fatigue lengthens the normal corrosion-fatigue life by strain hardening or shortens it by producing disarrayed metal which may be particularly susceptible to corrosion. With both cold-drawn and annealed mild steel wires, little or no change in corrosion-fatigue life was brought about by preliminary dry fatigue under the conditions tested. A metallographic study was also made of changes during air-fatigue and corrosion-fatigue processes. The annealed wires were electropolished to remove surface defects and to avoid deformation. Excellent photomicrographs illustrate the formation of micro and macro cracks. Discusses relations between corrosion fatigue and other forms of failure.—BLR.

2.3, 2.5

Tentative Method of Testing Chemical Anti-Rust Agents and Inhibitors in the Laboratory. (In German.) W. Wiederholt and B. Thiede. *Metalloberflache*, sec. A, **4**, 25-28 (1950) Feb.

Presents a systematic outline of the above method, analogous to ASTM methods used in the U. S.—BLR.

2.3, 4.4

Stress-Corrosion Tests on Turbo-Supercharger Materials in the Products of Combustion of Leaded Gasoline. G. B. Wilkes, Jr., General Electric Co. ASTM Preprint No. 60; 13 pp. (1950).

Stress-corrosion tests were made on 18 alloys. The corroding agents were the products of combustion of leaded aircraft gasoline. Tests were made under both constant temperature and cyclic temperature conditions. Under the conditions of these tests, the combustion products are somewhat corrosive if the temperature is cycled but not at constant temperature. The acceleration of strain due to temperature cycling alone has a greater detrimental effect on strength. From the results of these tests, certain speculations are possible concerning the process by which products of combustion of leaded gasoline cause corrosion. —TDD.

2.3, 5.4

Assessing Protective Value of Paint on Steel Surfaces. F. Wormwell and D. M. Brasher. *J. Iron Steel Inst.*, **162**, 129-135 (1949) June.

The authors give a description of an experimental technique for measuring changes with time of the electrode potential of painted steel immersed in artificial sea water. It is shown that conclusions drawn from the shape of potential/time curves during the first hours, or even days, may be quite misleading as a guide to the ultimate protective value of the paint. By continuing the measurements over much longer periods than have hitherto been used, the characteristic shape of the potential-time curve is obtained. The technique has been used to investigate the influence of the following factors: the thickness of paint, the type of surface finish on steel, the method of pretreatment before painting and the type of paint. It is concluded that changes in the electrode potential of painted steel immersed in artificial seawater provide valuable information on the corrosion resistance of metal/paint systems in marine conditions.—TIME.

2.3, 5.4

Corrosion and Passivation of Mild Steel at High Speeds of Movement in Aqueous Solutions. F. Wormwell and

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Phones JA-7222—KE-5136

H. C. K. Ison. *Chem. Ind.*, **1950,** No. 27, 549-550, July 8.

The formation of protective films on mild steel in rapidly-moving fresh waters was demonstrated with a rotor apparatus. In distilled water and in mains water at speeds of 750 and 1500 rpm the machined mild steel specimens remained virtually unattacked for seven days, provided the rotation was continuous. A period of stationary exposure at any stage in the test resulted in the onset of corrosion, but subsequent rotation again restricted the corrosion rate to small values. The formation of a protective film in the presence of concentrations of chloride ions as high as 0.1 N was unexpected, but tests indicated that the oxide film seldom formed and the usual result in salt was was widespread and immediate attack.

2.3, 4.6

The Determination of Dissolved Oxygen in Boiler Waters. R. S. Young, E. T. Pinkney and R. Dick. Nchanga Consolidated Copper Mines, Ltd. *Power Eng.*, 54, No. 7, 62-65+ (1950) July.

The article outlines the principal methods for the determination of oxygen in boiler waters. The advantages and disadvantages of these methods are discussed. Effect of sulfites, temperature and concentration of iodine, influence of starch and the removal of dissolved oxygen are included. 71 references.—INCO.

2.3

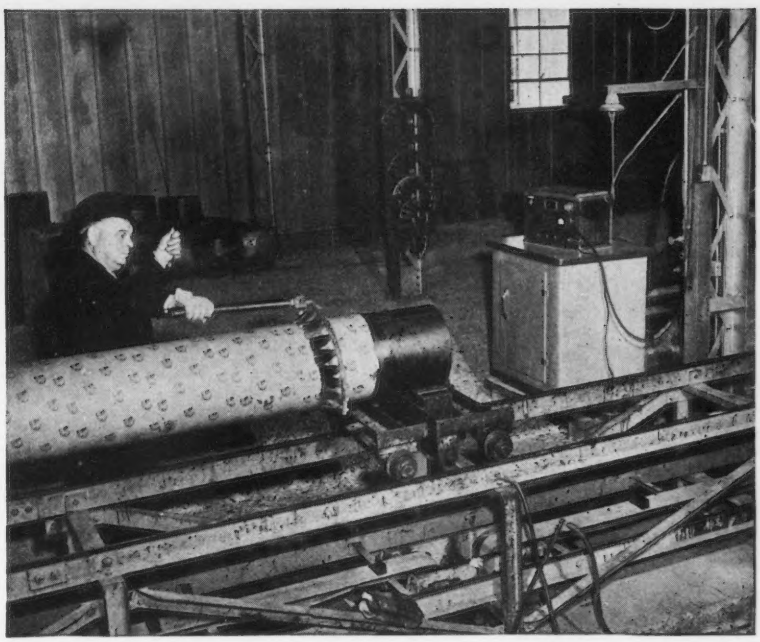
Stress Corrosion Tests. Paper by C. D. Weir, submitted to The Institution of Mechanical Engineers for written discussion, 1950.

The paper describes a series of tests carried out using an apparatus specially designed for stress-corrosion investigations at high temperatures. The specimens, which were of hollow form, were inserted into the base of an autoclave and loaded by means of a lever system, through a push rod inserted in the specimen. This arrangement permitted the production of accurate notch-forms on the external surface in contact with the sodium hydroxide solutions. It was found possible to produce failure of notched specimens rapidly and consistently, but homogeneously stressed specimens were immune. The fractures were inter-crystalline and typical of those occurring in practice. Dilute solutions, though not entirely impotent, were found to be very much less effective than those of high concentration. The presence (or absence) of silica in the solutions exerted no appreciable influence. Neither the addition of tannin nor the use of fine-grain steels was completely effective in preventing intercrystalline failure, though in the case of the latter, increased resistance was noted in some cases. Cathodic polarization was found to be protective while anodic polarization did not prevent and possibly hastened, failure.—TIME.

2.3, 3.2

Optical Studies of the Oxidation of Iron at Temperatures in the Range 20-265° C. A. B. Winterbottom. *J. Iron Steel Inst.*, **165,** 9-22 (1950) May.

Optical investigations were conducted, using an improved experimental technique. Methods and apparatus are briefly described. Results show that films up to 100-250 Å. in thickness consist mainly of magnetite, or possibly γ-ferric oxide,



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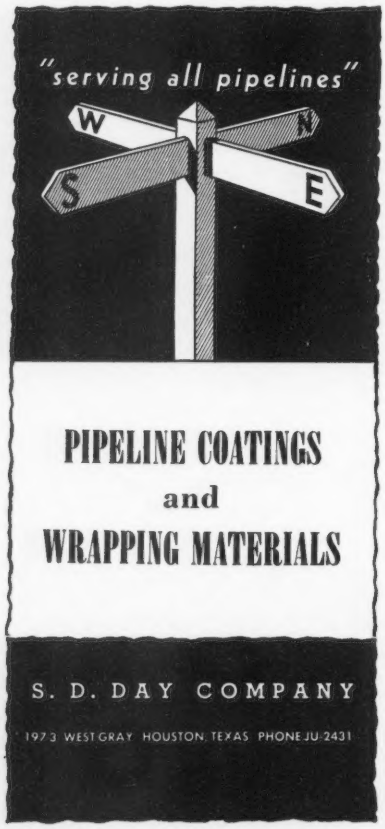
while on films of greater thickness an outer layer of α-ferric oxide is formed. Rate of film growth appears to depend on crystal orientation, atmospheric moisture and polish and cold work. The last retards film growth, possibly as a result of preferred orientation. The growth process does not appear to depend upon whether the film is formed on iron, or on ferrous alloys of the stainless type. 30 ref.

2.3, 3.2, 6.3

Hydrogen Embrittlement in Cadmium and Zinc Electroplating. C. A. Zapffe and M. E. Haslem. *Plating,* **37,** No. 4, 366-371 (1950).

Full details are presented of experiments carried out to determine the degree of hydrogen embrittlement taking place on mild steel and stainless steel during the deposition of cadmium from three different baths and of zinc from one acid bath and five cyanide baths. The method of assessing hydrogen embrittlement was to bend the specimen at a constant rate around a fixed pin. This provided an angle of failure which varied with the degree of hydrogen embrittlement. The mild steel used contained 0.18 percent carbon and had been cold drawn to a tensile strength of 170,000 lb. per sq. in. The stainless steel contained carbon 1·1, chromium 16·8 percent, and had been cold drawn to a 24·5 percent reduction of area. Both steels were in the form of 1/8 in. diameter wire, which in the unplated condition, could be bent through 180 degrees. The following tentative conclusions were reached. The mild steel was much less embrittled by any of the plating processes than it was by cathodic pickling or by straight hydrogen evolution in the plating solution. This result is consistent with the known current efficiencies of the solutions. The stainless steel was seriously embrittled by all the plating processes used, this embrittlement being more severe in certain cases than that caused by straight hydrogen evolution. This result is contrary to the known current efficiencies. On the basis of results with the stainless steel it is concluded that cyanide solutions for both cadmium and zinc uniformly exhibit a powerful hydrogenizing effect which seems affected neither by normal variations in composition nor by numerous reagents added to the bath as brighteners. Acid zinc solutions are much less severely hydrogenizing, as is the case with copper-plating baths. 11 references are appended.—MA.



2.3, 3.5, 3.4, 4.2

The Factors of Temperature and Humidity in the Corrosion of Metals in an Atmosphere of Sulfur Dioxide. (In Russian.) O. V. Zarubina and M. L. Turich. *J. Applied Chem. USSR,* **21,** No. 4, 362-371 (1948).

Gain-in-weight tests were carried out on aluminum, copper, brass, tinplate, nickel-plated steel, steel, soft iron, and cast iron, in air containing 5-6 percent sulfur-dioxide by volume at temperatures from 14 degrees to 40 degrees C, with relative humidities of up to 92 percent. The temperature was found to be the deciding factor, maximum corrosion taking place at 20°-25°C. There was little attack at 30°-35° C, even at relative humidities of 80-90 percent. With copper and brass, corrosion chiefly took the form of a change in color, and there was little increase in weight. The results obtained are in agreement with those experienced in fumigation.—MA.

2.3

Accelerated Weathering. Laboratoires Du Batiment et des Travaux Publics. *Trav. Peint.,* **4,** No. 11 bis (Special No.). 41 (1949).

The most usual cycle is: 1. One-half hour in ordinary water. 2. One-half hour at —15° C. 3. One-quarter hour warming up to the ambient temperature. 4. One-half hour exposure to sulfurous vapors (1 percent sulfur dioxide). 5. One hour exposure to UV light (60°-65° C). Panels of sanded mild steel and glass are used and careful attention must be paid to film thickness and brushing technique as well as to the time and conditions of drying.—RPI.

2.3

What You Should Know About Electrographic Testing. *Steel,* **126,** 56-60, 76 (1950) Jan. 23.

Recent developments in electrographic methods for identifying metals, alloys, and inclusions and for testing porosity in organic and metallic coatings.—MR.

2.3

Rain Erosion Properties of Plastic Materials. I-II — Interim Reports on Their Comparative Evaluations. U. S. Air Materiel Command Lab Report No. MCREXM-M5378; U. S. Air Materiel Command, Air Technical Index No. 20821; U. S. Dept. of the Air Force, Technical Report No. 5686; PB. 97575, 1948, May, 101 pp.; *Prev. Det. Abs.* **7,** Plas 113 (1950).

A simple laboratory apparatus was developed for accelerated comparison of the rain erosion resistance of plastics and other materials. A study of the effects of variation in temperature, angle of attack, droplet size and concentration and velocity of rainfall showed: 1. That the rate of erosion is a function of droplet size and velocity, and 2. That the angle of attack and the radius of the part exposed to the impingement of raindrops are important factors. A fiberglas/polythene laminate showed the best erosion resistance.—RPI.

2.3

Hydraulic Cylinder Varies Spring Load in Fatigue Tester. *Product Eng.,* **21,** 102-103 (1950) Feb.

Seamless steel pipe for use in oil-well drilling operations can be subjected to simulated service conditions in new corrosion-fatigue tester.—MR.

2.3, 4.6, 3.5

The Jet-Impingement Apparatus for the Assessment of Corrosion by Moving Sea-Water. R. May and R. W. De Vere Stacpoole. *J. Inst. Metals,* **77,** 331-344 (1950) June.

Failure of condenser-tube and seawater pipes occurs largely as a result of the corrosive-erosive action of air bubbles carried in the water stream. An apparatus which reproduces conditions favorable for this type of attack is described. Construction of apparatus, test procedure and evaluation of results are described.—BLR.

2.3, 5.9

Engineering Applications of Radioactive Materials. Phillip R. Marvin. *Non-Destructive Testing,* **8,** No. 3, 26-34 (1949-50).

A brief review is given on the type, energy and half-life, of radioactive isotopes and their selection for industrial uses. Radioactive isotopes may often be introduced within a substance, by placing it in a particle accelerator or nuclear reactor, or by using a radioactive isotope in synthesizing the substance, or by plating a radioactive element on the specimen. Marvin describes many applications, indicating the factors which lead to the choice of a particular isotope. The applications include: I. Radiography and thickness measurements, II. Tracer elements, as in a study of sulfur in steelmaking, III. Indicators, e.g. level gauges in closed containers, IV. Ion sources in gas discharge tubes, V. Static elimination, VI. Cleaning, contact, diffusion, corrosion and friction studies, VII. Measurements of water flow, VIII. Measurement of distribution of substances in others.—MA.

2.3, 5.3

Resistance to Corrosion of Hard Chromium Deposits. (In French.) P. Marisset. *Metaux & Corrosion,* **24,** 247-260 (1949) Nov.

Comparison of corrosion resistance in different media has value only if conditions of tests are identical. Results of tests in 160 different media under different conditions. 18 ref.—MR.

2.3, 4.2, 3.7, 5.4, 4.6

The Corrosion of Steel. *J. Iron Steel Inst.,* **165,** 287-300 (1950) July.

The following papers are discussed: "A Simple Form of Accelerated Atmospheric Corrosion Test," R. St. J. Preston: "A Study of the Corrosion Resistance of High-Alloy Steels to an Industrial Atmosphere," H. T. Shirley and J. E. Truman; "The Atmospheric Corrosion of Iron and Steel Wires," J. C. Hudson; "Climatic Effects on the Cor-

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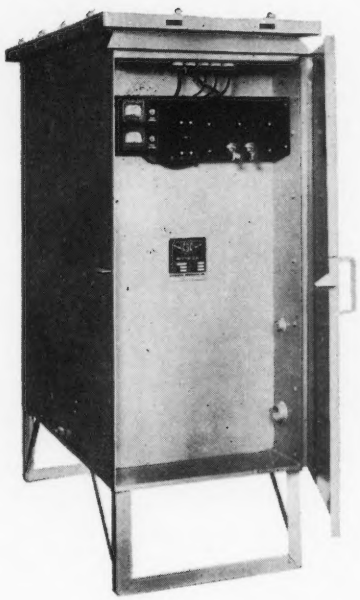

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rosion of Steel," J. Dearden; "The Effect of Shot-Peening Upon the Corrosion-Fatigue of a High-Carbon Steel," A. J. Gould and U. R. Evans; "Corrosion Fatigue of Steel Under Asymmetric Stress in Sea Water," A. J. Gould; "High Speed Rotor Tests of Paints for Under-Water Service," F. Wormwell, T. J. Nurse and H. C. K. Ison; and "Electrochemical Studies of Protective Coatings on Metals: Part I. Electrode Potential Measurements on Painted Steel," F. Wormwell and D. M. Brasher. The papers were published in 1948 and 1949 issues of the *Journal*.—BLR.

2.3, 8.9, 3.5

Laboratory Testing of the Rain Erosion Resistance of Aircraft Finishes. J. K. Grace and G. C. Frey. North Amer. Avia.; *ASTM Bull.*, **168**, 56-66 (1950) Sept.

Erosion has occurred on the surfaces of several modern airplanes during flight through rain. The eroded areas have been principally the surfaces of low-pressure, glass cloth-polyester laminates and organic finishing materials. Test equipment has been principally of two types: water-jet testers and whirling arm testers. The water-jet testers operate by impinging a high-velocity jet of water on a specimen. The jet is usually modulated or interrupted in some manner. The whirling arm testers move the specimen, at high speed, through a water spray simulating rain. Erosion somewhat similar in appearance to that obtained in service is obtained with both types of testers. In this paper, data from a jet-type tester are compared with previously reported data from a whirling arm tester. Both sets of data indicate that the time required for erosion failure of several plastic materials varies as the reciprocal of a large power of the velocity. The specific relation, however, differs greatly for the two testers, the velocity exponent being approximately 18 for the jet tester and 7 for the whirling arm tester. Certain plastic laminate configurations and certain organic finishes show markedly better rain-erosion resistance in tests than do conventional laminates and finishes.—TDD.

2.3, 6.4

Corrosion Figures (Etch Pits) by Anodic Attack. (In French.) R. Jacquesson and J. Manenc. *Compt. Rend.*, **230**, No. 10, 959-960 (1950) Mar. 6.

A technique for obtaining etch pits on cold-worked aluminum is described. The method consists of an anodic attack in a dilute solution of hydrochloric acid, using 0.6 amps. per sq cm.—RPI.

2.3, 5.4

Evaluation of Organic Coatings by Electrographic Printing. Max Kronstein, Marion M. Ward and Robert Roper. *Ind. Eng. Chem.*, **42**, 1568-1572 (1950) Aug.

Application of the electrographic printing method for the detection of permeability and underfilm spreading of moisture of organic coatings gives new means for the rapid evaluation of these coatings under many conditions and in conjunction with many of the usual test methods. The method has been used successfully over a period of nearly 3 years in the development and evaluation of new coatings and modifications of commercial coatings. The work reported is concerned with new applications of the method. Diagrams and illustrations.—BLR.

2.3, 4.2, 6.2, 3.5

Testing of Heat-Resistant Alloys for Resistance to Corrosion by Combustion Gases. (In French.) P. Galmiche. *Rev. Met.*, **46**, 843-848 (1949) Dec.

Eight different alloy steels were tested for the above, using an apparatus and procedure which are described and diagrammed. Surface microstructures are illustrated. Includes evaluation of effects of combustion-gas composition. — BLR.

2.3, 3.6

Distribution of the Corrosion Process Along a Tube. (In Russian.) A. N. Frumkin. *J. Phys. Chem., USSR*, **23**, 1477-1482 (1949) Dec.

Theoretically analyzes distribution of corrosion in an endless tube filled with electrolyte having a fixed potential applied at the exit. Such a situation is exemplified by having a tube of one metal inserted into the wall of a large reservoir of another metal filled with the same electrolyte. Corrosion is thus studied as an anodic process on the wall of the tube. Formulas for determination of distribution of potential inside the tube are proposed and interpreted for different values of the variables.—BLR.

2.3, 6.2, 4.3

Researches of Stainless Steels; Electrochemical and Weight Loss Measurements of the Corrosion Resistance of Some Stainless Steels. (In Italian.) L. Cavallaro and A. Ferri. Assoc. Ital. Met., 2nd Nat. Congress, May, 1948. Papers on Corrosion, 101-121.

Potentiometric and weight loss tests on several chromium and chromium-nickel steels in sodium chloride and hydrochloric acid solutions.—BNF.

2.3, 5.4

Discussion of Paper on Electrical Method for Evaluation of Protective Coatings as Moisture Barriers. *ASTM Bull.*, 51-53 (1950) May.

W. C. Ellis, E. G. Brink and C. Y. Hopkins discuss separately above paper by Marion A. Arthur. Includes author's replies.—BLR.

2.3, 5.4

Recent Development in Primer Coatings. Allen G. Gray. *Prod. Fin.*, **14**, 100+ (1950) June.

Deals with structural steel shop coat priming paint. Describes test procedure, pigmentations and vehicles. Discusses test results.—BLR.

2.3, 1.3

Factors To Be Considered in Using Salt Spray Testing. Allen G. Gray. *Prod. Fin.*, **14**, 58+ (1950) Mar.

Extensively reviews a few recent contributions to the above. Illustrated.—BLR.

2.3

Correlation of Accelerated Weathering Machines. R. W. Hill, G. S. Cook and W. E. Moyer. *ASTM Bull.*, **164**, 32-43 (1950) Feb.

A detailed report on tests to compare two commercial weathering machines, the Atlas Twin Arc Weatherometer and the National Carbon XIA Accelerated Weathering Machine. The amount and type of change of color on carefully prepared painted test panels was proved to be a reproducible test of the effects of exposure in the machines. It was found that, working under certain specified conditions, the results from the two machines could be correlated.—ZDA.

2.3, 5.4

Electro-Chemical Evaluation of Organic Coatings for Food-Container Closures. W. K. Schneider, D. L. McConaughy and G. W. Seagren. *Food Tech.*, **3**, 192-195 (1949); *Brit. Abs., C*, 440 (1949).

A technique is described which tests the effectiveness of organic coatings on the metal closures of glass food containers. It involves passing a direct current from a 2-volt source for 16 hours through an electrolyte solution containing sodium chloride (15 percent) and maleic acid (1 percent), using a piece of coated closure both for anode and cathode. The

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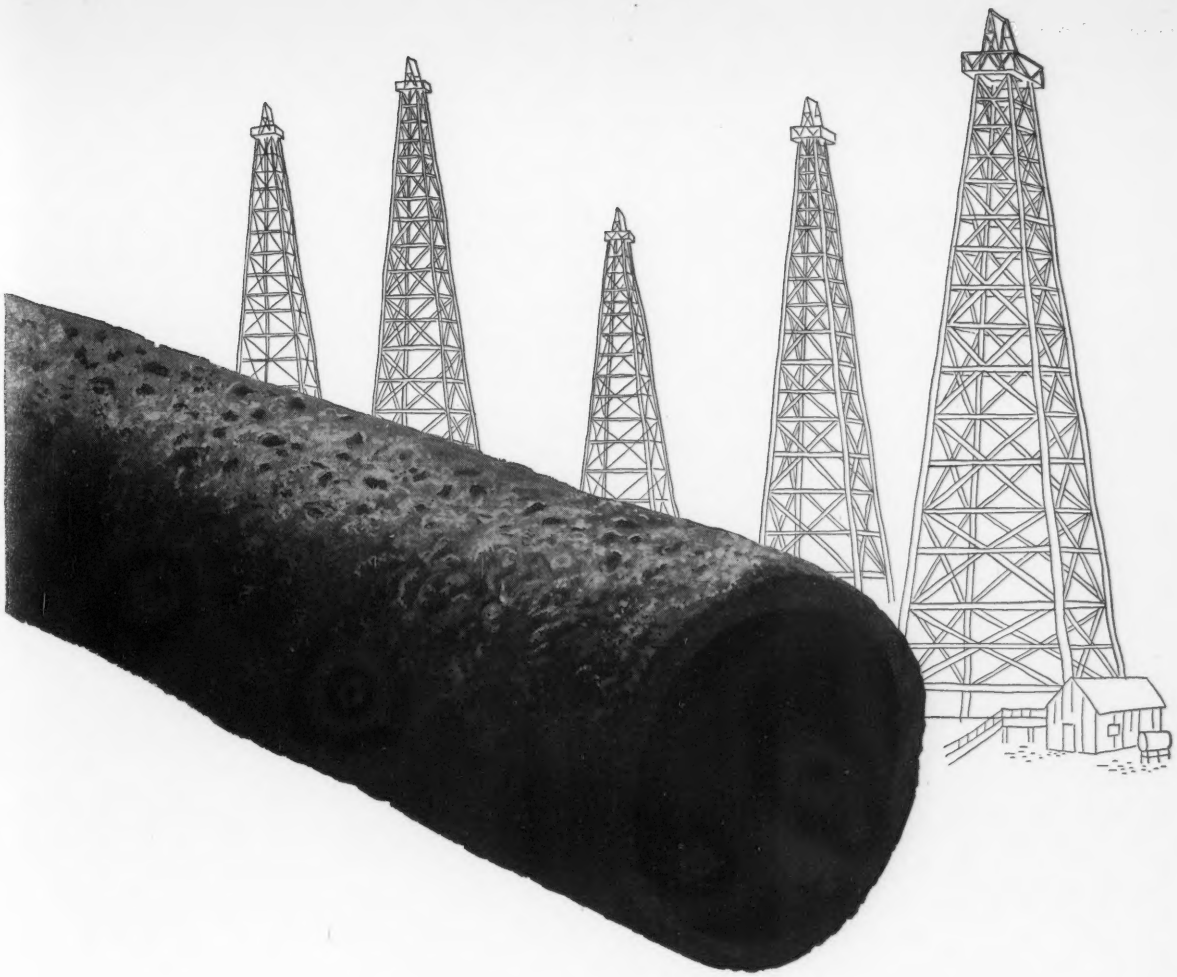

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amount of organic coating which is removed by the treatment is a measure of the effectiveness of the coating. It is claimed that the method develops at an accelerated rate those changes which cause perforations of closures under normal storage conditions. A possible mechanism of this type of corrosion is suggested.—RPI.

2.3

A Fully Automatic Weathering Machine. V. Virtala. *Paint Tech.*, **15,** No. 170, 55-58 (1950).

An enclosed tank-type machine is described, which it is claimed gives results comparable to outdoor exposure in Finland and weathers approximately 10 times more rapidly than natural weathering for paints, 25 times more rapidly for lacquers and 12 times more rapidly for roofing felts. Panels (roofing felt, paint, lacquer, or metal coating specimens, etc.) are subjected in turn to units producing dry (mercury vapor lamps, warm air current and ozone), humid (fine and heavy water sprays and ozone and irradiation if required) and frosty (down to —30°C) conditions, to which they are exposed for 9⅓, 9⅓ and 5⅓ hr, respectively. Ultra-violet light of λ 2900-4800 Å is regarded as more chemically active than that > 4800 Å, and the lamps used emit about 50 percent of their energy in this region compared with 17.4 percent for the sun and 24.6 percent for carbon arc lamps. The intensity of radiation falling on the panels is about 7 times that from the sun in the region 2900-4800 Å, and about 2½ times over the whole spectrum.—MA.

2.3

Metallurgical Applications of the Electron Microscope. G. A. Geach. *Metallurgia,* **41,** No. 242, 115-120 (1949).—MI.

2.3

Testing Materials at High Temperature. F. G. Tatuall. *Mech. Eng.*, **71,** No. 11, 906-910 (1949).—MI.

2.3

Electron Microscope and Diffraction Study of Metal Crystal Textures by Means of Thin Sections. R. D. Heidenreich. *J. Appl. Phys.*, **20,** No. 10, 993-1010 (1949) Oct.—MI.

2.3, 5.4

Electrochemical Methods of Evaluating Anti-Corrosive Paints and Varnishes. L. Cavallaro and C. Bighi. *Peint Pig. Vernis,* **26,** No. 4, 141-143 (1950).

In these experiments mild steel panels protected with a) boiled linseed oil, b) an oil/resin varnish, c) red lead in boiled linseed oil, d) iron oxide kaolin in boiled linseed oil, e) zinc chrome in boiled linseed oil, f) lead arsenate in boiled linseed oil, were immersed in a 3 percent solution of potassium sulfate. The current passing between the panel and a platinum cathode was measured. The results are recorded on graphs. Of the pigments, red lead afforded the best protection. A three coat system is better than either a one- or two-coat and a stoved film better than an air-dried one.—RPI.

2.3, 6.2

Contributions to the Study of the Stainless Ferrosilicons. III. Mechanical and Chemical Properties. (In French.) Robert Lefebure. *Metaux & Corrosion,* **25,** 67-83 (1950) Mar.

Different methods for determining mechanical properties and corrosion resistance are described. Data for different compositions are discussed. Applications of the stainless ferrosilicons are described. 48 ref.—BLR.

2.3, 3.6

A Polarographic Method for the Indirect Determination of Polarization Curve for Oxygen Reduction on Various Metals. I. Description of the Method—Case of Platinum. II. Application to Nine Common Metals. Paul Delahay. *J. Electrochem. Soc.*, **97,** 198-212 (1950) June.

Deals with electrolytic reduction. The complete polarization curve was determined. Contributions of the two- and four-electron reduction processes, i.e., reductions of oxygen to hydrogen peroxide and to nitrous oxide are also calculated. Equilibrium conditions are derived from thermodynamic data. The above is applied to aluminum, zinc, magnesium, nickel, iron, silver, copper, tin and lead. Results are plotted and discussed. 30 ref.—BLR.

2.3, 7.1, 4.4

New Engine-Wear Tests. *Oil Gas J.*, **49,** No. 12, 162 (1950) July 27.

A new test method requiring runs of only about three hours permits determination of engine wear after very short periods of engine operation. Comparative runs using many different types and grades of lubricating oil are possible under identical operating conditions. During engine operation, minute particles of radioactive iron are worn from a radioactive piston ring and become suspended in the crankcase oil. Following the brief running period, the oil is withdrawn from the crankcase and a sample is poured into a specially designed graduate. A metal cylinder containing a Geiger counter is dipped in the sample and the amount of the radioactive iron is recorded.—INCO.

2.3, 5.4

New Developments in the Testing of Organic Coatings by the Electrographic Printing Method. M. Kronstein, M. M. Ward, and R. Roper. Papers presented at the Atlantic City Meeting of the Div. of Paint, Varnish & Plastics Chem., Am. Chem. Soc., 214-219 (1949).

The electrographic printing method is used for testing insulating varnishes on fabric or paper. It can also be employed in testing the permeability of paint films applied to nickel, copper, cadmium or other metals. The painted panel and photographic paper soaked in an electrolyte are placed between two aluminum electrodes under specified pressure. Various solutions are used as a developer, e.g., for copper and cadmium, sodium sulfide developer is used. Brittleness of the film is also detected by this method. —RPI.

2.3

"AC"—A New Corrosion Test. T. E. Lloyd. *J. Metals,* **188,** 1092-1093 (1950) Sept.

Test strips of metals mounted on a turntable revolving at the rate of 15 turns per hour are passed alternately through water saturated air at 160 degrees-170 degrees F and then through air at 70 degrees F and a relative humidity of 25 percent. This new test is claimed to closely approximate actual weather conditions and is sufficiently accelerated to make it adaptable where time is short and concrete evidence is required.

2.3, 3.5

Effect of High Shear Rate on Erosion of Common Bearing Metals. Charles D. Strang and Thomas P. Clark, U. S. National Advisory Committee for Aeronautics, Cleveland, Technical Note 1887, 25 pp., illus., diagrs. (1949) June.

The object of this investigation was to determine whether high shear rates and corresponding high shear stresses could cause erosion in journal bearings. The method consisted of forcing oil of high viscosity between two closely spaced plates, one made of hardened steel and

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Detroit's answer was to install cathodic protection, using graphite ground anodes to protect the metal piping. Sixty-eight 4" x 40" "National" graphite anodes were placed under each garage. Two anodes were placed in each hole made through the concrete floor, the holes being spaced 57' to 102' apart. Cost of this installation, which is providing ample protection, was only $15,000.

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the other of the bearing metal to be eroded.

When filtered oil was used, annealed copper, silver and lead were undamaged after six hr; lead was unharmed after 14 hr. Surface finish marks and intentionally made scratches and indentations failed to act as nuclei for erosion. Sharp edges left at scratches were not rounded or smoothed by oil flow.

When unfiltered oil was used a pseudo-erosion resembling erosion in aircraft power plants was obtained. Visual observation showed it to be caused by small foreign particles, probably wear particles from the high pressure pump. These caused many small scores in the surface of the specimen. Another type of erosion resulted from the sandblast action of particles smaller in diameter than the minimum thickness of the oil film. These particles strike the surface of the erosion specimen at regions where the oil flow was forced to change direction. Part of the erosion in power plants may be of this nature.—PBA.

2.3, 5.3

Adhesion of Hard Nickel to High-Strength Aluminum Alloy Metal Finishing. B. B. Knapp, Int. Nickel Co., Inc., New York. **47,** No. 12, 42-46 illus., tables, diagrs. (1949) Dec.

The adhesive strength of many metallic coatings on sheet material can be measured quantitatively by a modified Ollard test in which the bond strength is measured under a pure tensile stress applied in a direction normal to the interface.

In this test the electrodeposit on the sheet has to be built up to a minimum thickness to maintain the separation in pure tensile stress. If the deposit is too thin, it tends to cup around the top edge of the hole, and a low value is obtained because of the introduction of a shearing stress. For adhesive strengths in the range of 15,000-20,000 psi a chloride nickel deposit of about 0.035-in. or a Watts nickel deposit of 0.050-in. is required. Adhesion strengths up to 60,000 psi require about 0.060-in. of chloride nickel.

Limited tests indicate the method is consistent and accurate.—PDA.

2.3

Corrosion Testing. D. H. Garside. *Ind. Heating Eng.,* **11,** 21-23+ (1949); *J. Iron & Steel Inst.,* **164,** Pt. I, 123 (1950).

Ordinary and accelerated corrosion tests are discussed, with notes on the Weatherometer and Richard's "industrial fog chamber." The tentative B. S. Specification for a method of testing the performance of protective coatings is given and critically examined and recommendations are made for conducting a series of tests.—RPI.

2.3

Study of the Metal Surface with the Electron Microscope. W. Feitknecht, K. Huber. *Met. Ital.,* **42,** No. 2, 53-57 (1950) Feb.

The different systems of the technique to obtain the replica of the etched metal surface to be observed at the electron microscope are described. The etch was always preceded by electrolytic polishing. The paper is accompanied by many electron micrographies—chiefly corrosion figures—obtained on various metals with the electron microscope of the Institute of Inorganic Chemistry and Physics of the University of Berne, Switzerland.—MI.

2.3, 5.4

Method of Analysing Rust-Preventing Paints. Kerchow and Wurzschmitt. PB, 70192, Frames 7522-7530; Board of Trade, Ger. Div., FD. 1537-49.

A method of analyzing rust-preventing paints to a composition specification is given.—RPI.

2.3, 8.8, 6.5

Resistance to Corrosion (by Tanning Solutions) of Metals, Alloys and Stainless Steels. P. Chambard and F. Abadie. *Bull. Assoc. Franc. Chim. Ind. Cuir,* **11,** 142-159 (1949). *C. Abs.,* **43,** 9506 (1949).

Tests were made on nickel A), Monel B), Inconel C), and two stainless steels D) (chromium 18%, nickel 8%, molybdenum 3%, copper 0.5%, and E) (chromium 18%, nickel 8%). Plates of these materials were immersed in solutions at various temperatures and the loss in weight (mg per sq. cm.) was determined at intervals up to 30 days. In sodium dichromate 100 parts, sulfuric acid (93%) 100 parts, water 100 parts, at room temperature, losses after 30 days were A) 0.7, B) 330, C) 0.2, D) 20, E) 20; at 95°-100° C all were strongly attacked. In pickle liquor (sulfuric acid 2 parts, sodium chloride 12 parts, water 100 parts) losses at 30 days were A) 3, B) 7, C) 2, D) 6, E) 36 at room temperature and 2-3 times as great at 32° C. In chestnut extracts (density 1.043, pH 2.9) losses were A) 1, B) 1.5 at room temperature, and A) 2.2, B) 0.8 at 35° C.; losses for C), D) and E) were negligible. No discoloration of the liquor occurred in any case. In two-bath chromium tanning liquors (2 days in sodium dichromate 6 parts, commercial hydrochloric acid 4 parts, water 100 parts, followed by 4 days in sodium dichromate 6 parts, commercial hydrochloric acid 10 parts, sodium thiosulfate 20 parts, water 100 parts) B) lost 20 mg per sq. cm. in the first bath, but nothing in the second, and the others were practically unattacked in either bath. Recommendations are that for reduction of bichromate, none is suitable; for pickle liquors, C); for contact with vegetable tan liquors, all are suitable, C) and D) being best; for two-bath chromium tanning liquors, any except B) may be used.—MA.

2.3, 7.1

Investigation into the Possibility of Obtaining a True Picture of the Cavitation Phenomena Occurring in Practice at the [Ship's] Propeller By Tunnel Tests. J. D. Van Manen. Department of Scientific and Industrial Research Translation from *De Ingenieur,* **61,** No. 23, Tech. Note 4, (1949).

Mathematical theory of the design of model wake-adjusted propellers for testing in the cavitation tunnel and of full-scale propellers (that of the S.S. Simon Bolivar being calculated as example).—RPI.

• Instrumentation

2.4

Advances in Inspection. Dorian Shainin. *Tool Engineer,* **24,** 17-21 (1950) Mar.

Reviews recent developments in fixed type gaging, discussing increased applications of the principles of optics, electronics, and airflow.—BLR.

2.4

Non-Destructive Testing of Metals. Rebecca H. Smith. *Western Metals,* **7,** No. 11, 32-34 (1949).—MA.

2.4, 6.4

Non-Destructive Magneto-Inductive Testing of the Aluminium-Magnesium-Zinc Alloy Hy43. G. H. Vosskuhler. *Metall,* **3,** Nos. 15 & 16, 247-251; Nos. 17 & 18, 292-295 (1949).

A detailed description is given of the application of the Durokawimeter, an eddy-current instrument, to the non-destructive testing of light metals, particularly the aluminium-base alloy Hy43, containing zinc 4-5, magnesium 3-5, and copper 0-5 percent. By making use of the relationships which are found to exist between a) tensile properties and hardness, and b) hardness and electrical resistance, the instrument can be used for the routine works inspection of parts which have been: 1. solution-treated, 2. cold-aged, 3. hot-aged and 4. forged.—MA.

2.4

General Material, Process, and Quality Control by Non-Destructive Testing. Milfred J. Parker. *Non-Destructive Testing,* **8,** No. 2, 15-17 (1949).

The routine use of non-destructive testing, with particular reference to magnetic methods, is discussed. The factors influencing the choice of the method and the stage at which it is applied are examined.—MA.

2.4, 7.1

Non-Destructive Testing and Inspection as Based on Factory and Field Operations. Kenneth E. Rush. *Non-Destructive Testing,* **8,** No. 2, 30-32 (1949).

Dealing with Diesel engine parts, the author describes the following forms of non-destructive inspection; a) dimensional checks; b) surface finish; c) physical properties, (e.g. Brinell, scleroscope, Magnaflux, etc.); d) miscellaneous, e.g. checking components in an assembly, engine tests, etc.—MA.

2.4

The Measurement of the Wall Thickness of Light Metal Castings with Dr. Förster's Sondenkawimeter. Ph. Schneider and P. Dekker. *Metall,* **3,** Nos. 19 & 20, 321-326 (1949).

The instrument consists of: 1. A small HF generator which supplies current to 2. An alloy iron core connected to 3. A phase-change meter, and 4. A small permanent magnet probe, separated from but on the longitudinal axis of 2. Variations in the distance between 2. and 4. alter the degree of phase change. This latter is further affected if a non-magnetic material is inserted between, and in contact with the core and the probe, the amount of the superimposed change depending on the nature and thickness of the material. Consequently, provided the nature of the inserted material is kept constant, the meter can be calibrated to indicate its thickness directly. The influence of various factors such as alterations in the air temperature, surface conditions of the material to be tested, and malalignment of the core and probe are discussed. The applications of the instrument to the determination of the wall thickness of light metal castings are described.—MA.

2.4

A New Coating Thickness Measuring Instrument. *Metal Fin.,* **48,** No. 5, 64-66 (1950) May.

Measurement of the thickness of non-magnetic coatings on steel can be carried out by electro-magnetic methods. The

magnet is coupled to the instrument and held in suspensoid by an electromagnetic field. The weighing operation is performed by means of a self-compensating magnetic balance, and the field strength is induced by a single solenoid. The instrument, its principle of operation, methods of testing and sources of error are discussed.—INCO.

2.4, 8.4

Magnetic-Particle Inspection — Applications in the Petroleum Industry. W. E. Thomas, Magnaflux Corp. Paper before API, Production Div., Spring Mtg., Cleveland, Apr. 1950. *Oil Gas J.*, **49**, No. 5, 53, 70+ (1950) June 8.

Magnetic-particle inspection can be used for magnetic material, but is of no use for austenitic alloys and non-ferrous materials. It depends for its operation on the fact that, if a crack occurs in a magnetized material and is so located as to be transverse to the direction of the magnetic field in the material, that field is distorted and the flux lines are deflected around the ends of such an obstruction. If the discontinuity actually breaks the surface, the leakage field is quite strong and highly localized. Alternating current is more effective for determining surface cracks, while dc is used for sub-surface cracking. This method is used in the petroleum industry to determine fatigue cracking of drill, production, transportation and refining equipment.—INCO.

2.4

Noncontacting Thickness Gauge Using Beta Rays. C. W. Clapp and S. Bernstein. *Elec. Eng.*, **69**, No. 4, 308-310 (1950) Apr.

The great success of using X-rays to measure the thickness of steel as it is being rolled in a hot-strip rolling mill has stimulated study of the possibilities of using other types of radiation in a similar manner. Of these, beta rays appear to hold the greatest promise. By measuring the energy lost by a stream of beta particles in passing through a sheet of material, the thickness of the material can be determined. Strontium 90 was used as the source of beta radiation and an ionization chamber registered the beta-ray intensity. Diagrams of the beta-ray thickness gauge and a photograph show the components and arrangement of the equipment, and the operation and calibration of the equipment is explained. —TDD.

2.4, 5.3

Investigation of Magnetic Particle Inspection of Electroplated Materials. J. W. Jakubowski, U. S. Naval Air Material Center, Philadelphia. Report AML NAM 25608, Part II, 31, No. 1, plates, tables, diagrs. (1948) Oct.

The interference of chromium plating with magnetic detection of surface and subsurface defects in the base metal was investigated, using both the circular and longitudinal magnetization techniques of the magnetic particle detection method for aircraft parts.

When the defect occurs at a progressively greater depth beneath the original unplated surface, a chromium plating thickness of a correspondingly lower order will mask its presence. Some of the flaws were not detected on the unplated surface with the residual method because of their excessive distance from the inspecting plane; hence this technique could not be relied upon

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to produce conclusive evidence of the extent of masking.

The difficulty of detecting surface flaws by the continuous circular magnetization technique increases with the depth of the defect; in effect, more leakage flux is present as a result of the increase in depth of defects, the faces of which act as local poles. The chromium plating thickness at which masking occurred was about equal to the depth dimension of the defect being masked; the influence of the width of the defect was neglected, since the depth of the flaw exerts the greatest influence on its detectability. When testing the defects by means of residual magnetism, the depth of crack had very little influence on the plating thickness necessary to mask the indication.

A standard navy type dc horizontal Magnaflux machine was used in all tests. —PDA.

2.4

Ultrasonic Testing. Donald Erdman. *Non-Destructive Testing,* **8,** No. 2, 28-30 (1949).

The various techniques of using ultrasonic waves for non-destructive inspection and for measuring specimen thickness are discussed. Special reference is made to the method of flaw detection in which the specimen is immersed in water. The waves can then be directed at any angle to the specimen, so that specimens of awkward shape may be examined more readily.—MA.

2.4

Testing and Inspection. J. T. Stacy. *Metals Rev.,* **22,** No. 5, 5-8 (1949) May.—MI.

2.4

Ultrasonics and Their Use for Non-Destructive Testing of Materials (Concluded). N. G. Neuweiler. *Microtecnic,* **1950,** 60-66, Mar.-Apr.

The basic working principles of the Hughes supersonic flaw detector are described together with a discussion of the ultrasonic method of flaw detection in forgings. The piece of material to be tested by the flaw detector is explored from one surface by means of a transceiver unit. A short pulse of supersonic energy is transmitted into the piece being tested and the energy is reflected back to the explored surface from the bottom of the piece or from any discontinuity within the materials. A cathode-ray tube is used for showing the instant of transmission and the moment of arrival of the echo or echoes. The energy reflected from a discontinuity arrives back at the explored surface before that which is reflected from the bottom and will be indicated on the time scale. Since the cathode-ray-tube time scale is at the same time a depth scale, the depth of the discontinuity beneath the explored surface of the piece or the actual depth of the piece may be gauged.—TDD.

2.4

A Survey of Modern Theory on Welding and Weldability. D. Seferian. *Sheet Metal Ind.,* **27,** 241-253 (1950) Mar.

Describes and illustrates the various types of weld defects, their causes and prevention. Surveys destructive and non-destructive weld-inspection methods.

2.4

Localization of Defects by X-Rays, by F. Baldi. *Met. Ital.,* **42,** No. 4, 133-135 (1950) Apr.

The paper describes a method for the localization of the defects in metal parts which is based on taking two radiographs on two separate films. The results are satisfying and the order of precision is more than sufficient for the normal controls.—MI.

2.4

A Supersonic Apparatus for Non-Destructive Testing of Materials. Herbert and Josef Krautkramer and Otto Rudiger. *Arch. Eisenhuttenw.,* **20,** 355-358 (1949) Nov. 12.

A supersonic apparatus for the non-destructive testing of materials and having a high power of resolution, is described. A 1-megacycle per second wide frequency band is used at 10 megacycles per second sound frequency. With this apparatus, defects of 0.5 mm diameter in a material thickness of 3 mm can easily be determined without interference effects. It is not necessary that the surface of the test-piece be flat. Examples are given in the field of application of this apparatus, especially relating to the testing of hard-metal alloy plates for cracks and piping.—MA.

• Standardization and Specifications

2.5, 1.7, 4.4

Corrosion Tests for Soluble Oil Dispersions. *J. Inst. Petr.,* **26,** 148-163 (1950) Mar.

The Cutting Oil Panel of Sub-Committee No. 6—Lubricants, was established in October, 1945 under the Chairmanship of Dr. N. L. Anfologoff to consider what tests for cutting oils required to be recommended for standardization as I. P. methods. The need for a corrosion test for soluble oil dispersions received its immediate attention and the panel has carried out a considerable amount of experimental work culminating in the formulation of a tentative standard method based on the existing Lloyd-Beeny or Herbert corrosion test. Whether the method is eventually adopted as a standard method or whether it is replaced by another method will depend upon future experience, but there will certainly come a time when the method is again under review. Therefore the panel has thought it of interest to publish a fairly comprehensive account of its work in connection with this method so that the results may be available to future workers in this field.—GPC.

2.5, 4.4

Corrosion Tests for Soluble Oil Dispersions. Cutting Oil Panel of Standardization Sub-Committee No. 6—Lubricants; *J. Inst. Petroleum,* **36,** 148-163 (1950) Mar.

A described tentative standard method for determining corrosion by soluble cutting oils appears reasonably accurate only in the extreme ranges of high corrosion or no corrosion. The procedure consists of bringing the aqueous dispersion of the oil into contact with the test metal under standard conditions. Oils which give corrosion in the tests do not necessarily corrode in practice.

CORROSION TYPES & INFLUENCING FACTORS

• Types

3.2

The Mode of Growth, Orientation, of Cuprous Oxide Layers on Monocrystalline Copper Spheres. (In German.) E. Menzel. *Ann. Physik,* **6,** No. 5, 163-180 (1949).—BNF.

3.2

The Effect of Environment on the Stress-Rupture Properties of Metals at Elevated Temperatures. O. C. Shepard and W. Sohalliol, Stanford Univ. Paper before ASTM, 53rd Ann. Mtg., Atlantic City, June 26-30, 1950. ASTM, Preprint No. 58, 5 pp. (1950).

Stress-rupture tests in controlled atmospheres were made with low carbon steels and with Hastelloy C. Small differences in the composition of environment produced relatively large differences in the amount of intergranular cracking and in the time to failure. Attention is called to the need for making stress rupture tests of metals in environments similar to their service conditions. —INCO.

3.2, 6.3

Electron-Diffraction Study of the Oxidation of Zinc Surfaces Prepared by Cleavage or Vaporization. H. Raether. *J. Phys. Radium,* **11,** No. 1, 11-19 (1950).

Electron diffraction shows that the surfaces of freshly-cleaved zinc crystals are covered with a layer of monocrystalline oxide having a normal lattice (no pseudomorphism) and with an orientation corresponding with that of the underlying metal (epitaxy). The internal potential of zinc is found to be 13·9 ± 1·5 V. The structure of the surface did not change after more than a month's exposure to air at atmospheric temperature. On heating the zinc surface to 200-400 degrees C in air the thickness of the oxide layer increased and its monocrystalline structure was transformed into a markedly oriented powder of large oxide crystals in the form of needles. Evaporated surfaces of zinc yield a Debye-Scherrer diagram, the oxide which covers the metal providing a number of rings. Exposure of the surface to air at atmospheric temperature, as in the case of the cleaved surface, produces no change of the diagram. At 180 degrees-350 degrees C. the oxide film increases in thickness and is changed into an oriented powder.—MA.

3.2, 3.7

Intergranular Corrosion. W. D. Robertson. *J. Metals,* **188,** No. 5, 790-791 (1950) May.

Published work is quoted which tends to show that intercrystalline corrosion is related to the relative orientation of adjacent grains. Various copper alloys and iron-nickel alloys are liable to intercrystalline corrosion when there is random orientation of the grains. Such orientation has been observed in samples where the concentration of impurities exceeds that known to be critical in intercrystalline corrosion. It is suggested that a study of the chemical and mechanical properties of grain boundaries as a function of orientation may help to explain the established phenomena. 7 references.—ZDA.

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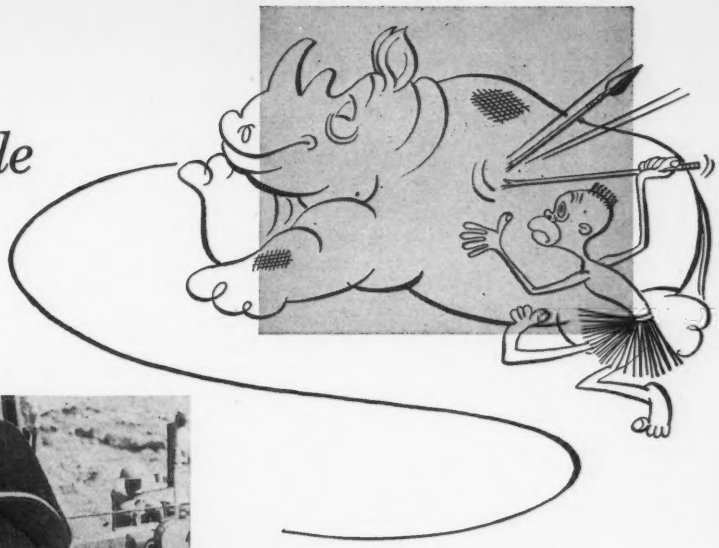

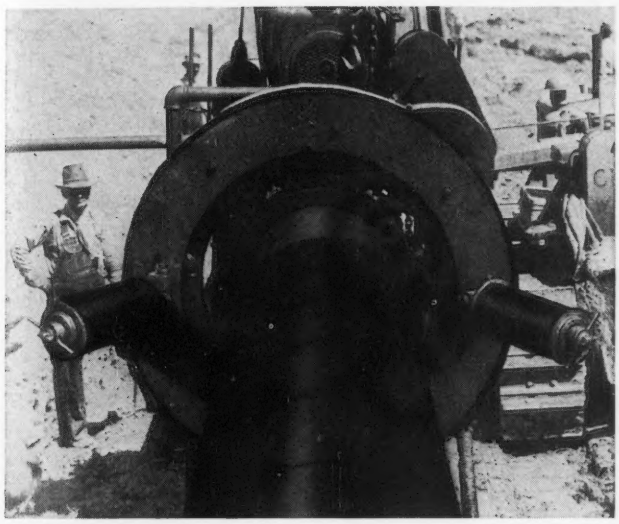

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3.2

Plug Dezincification in Cartridge Brass. A. L. Simmons. *Metal Prog.*, **57,** No. 4, 496-497 (1950) Apr.

Plug dezincification occurring on the surface of brass consisted of a copper stain surrounding a small central hole or crater. Sometimes the hole was empty but sometimes it contained loose spongy deposits of copper, or an inclusion of non-metallic character, or a metallic inclusion such as a particle of lead or steel. Trouble of this type showed up only after vats were replaced with spray pickling machines. Causes and mechanism of formation are discussed. Was encountered in Government Ammunition Factory, Melbourne, Australia.—INCO.

3.2, 6.3

Intergranular Embrittlement [of Copper]. H. H. Symonds. *Metal Ind.*, **76,** No. 7, 127-128 (1950).

The fracture of an extruded copper section on bending was found to be due to intergranular embrittlement resulting from treatment in a partially reducing atmosphere.—MA.

3.2, 3.5, 6.4

Action of Corrosion and Stress on 13 Cr Stainless Steel. H. H. Uhlig, M. I. T. *Metal Prog.*, **57,** No. 4, 486-487 (1950) Apr.

Strips of 12.5 chromium—0.1 nickel—0.12 carbon — 1.2 copper — 1.2 silicon stainless steel were U-bent and immersed in distilled water and 3 percent sodium chloride. Rusting and pitting soon occurred in the salt solution but only after 4½ months did one specimen finally crack. One specimen stressed as above was coupled to a sheet of aluminum foil and submerged in the salt solution. With this arrangement the stainless steel strip cracked overnight, thus suggesting that cathodic polarization was the critical factor causing rapid failure. When a platinum anode was used in a salt solution cell with the stressed specimens as cathodes, specimens broke. Using dilute sulfuric acid containing a few drops of white phosphorous dissolved in carbon disulfide to accelerate hydrogen adsorption by the alloy, cracking occurred again. These experiments suggest that so-called stress corrosion cracking of this martensitic type stainless steel may occur under any condition that favors discharge of hydrogen ions on the surface. Specimens after brief cathodic polarization in sodium chloride or sulfuric acid are exceedingly brittle, but on standing in the air the usual ductility is regained. Failure by cracking of the stressed martensitic stainless steels exposed to a corrosive environment may probably best be described as hydrogen embrittlement.—INCO.

3.2, 6.3

Hydrogen Embrittlement in Nickel, Tin and Lead Electroplating. C. A. Zapffe and M. E. Haslem. *Plating*, **37,** No. 6, 610-613 (1950).

Several nickel-, tin-, and lead-plating baths have been investigated and it is concluded that: 1. Ordinary mild steel is relatively immune from hydrogen embrittlement, whereas stainless steel is particularly sensitive. 2. The conventional Watts nickel-plating bath shows the least embrittlement of any process studied, with the exception of the dilute fluoborate lead bath. 3. A commercial nickel bath with brightening and antipitting agents present has a somewhat greater tendency to cause hydrogen embrittlement than the Watts bath. 4. Acid tin plating causes about the same degree of embrittlement as acid zinc and acid copper plating. 5. Alkaline tin plating causes embrittlement of mild steel exceeding that observed in any other processes. The embrittlement of stainless steel by this bath is virtually the same as that produced by other cyanide baths. 6. Hydrogen peroxide added to the alkaline tin bath has no effect on embrittlement. 7. The dilute fluoborate lead bath causes the least embrittlement of all baths studied, whereas the concentrated fluoborate baths cause fairly severe embrittlement which rapidly disappears with prolonged plating time. 4 references.—MA.

CORROSIVE ENVIRONMENTS

• Atmosphere

4.2, 6.5

Temperature Dependence of Emission of Photosensitive Particles During the Atmospheric Corrosion of Magnesium and Zinc. (In Russian) I. L. Roikh and F. E. Mazaev. *Reports of the Academy of Sciences of the USSR*, new ser., **72,** 335-338, (1950) May 11.

Analysis of experimental data on the above resulted in development of an empirical equation for the above relationship and for the energy of activation of the photosensitive particles.—BLR.

4.2, 1.6

Vertical Distribution of Photographically Active Particles, Precipitated From Metals by Atmospheric Corrosion. (In Russian) I. L. Roikh. *Reports of the Academy of Sciences of the USSR*, new ser., **70,** 253-256, (1950) Jan 11.

Claims that certain of the above effects were obtained with magnesium, aluminum and zinc. Quantitative data are given for variations of this effect with surface condition of the samples. No explanation is given for the peculiar phenomena reported.—BLR.

4.2, 3.2, 6.2

The Behaviour of Nickel-Chromium-Iron Alloys in Carbon-Bearing Gases in the Range 900°-1000°C. D. M. Dovey and I. Jenkins. *J. Inst. Metals*, **76,** 581-596 (1950) Feb.

Corrosion of nickel-chromium electrical-resistance alloys used at 900-1000 degrees C in partially burned manufactured gas was investigated. The corrosion, which is shown to be due to simultaneous carburization and oxidation of the alloy with rapid intergranular oxidation in depth, is typical of that known as "green rot." Order of attack was less in alloys containing iron and the presence of approximately 2 percent silicon was sufficient to suppress the corrosion completely. Possible factors governing the corrosion mechanism are discussed and importance of the oxide layer as a barrier to carbon entry into the matrix is demonstrated. Includes macrographs and micrographs. 14 ref.—BLR.

• Chemicals Inorganic

4.3, 3.4

The Dissolution of Metals Over the Temperature Range 25°C to —60 C. I. The Dissolution of Magnesium in Hydrochloric Acid-Methyl Alcohol-Water Solutions. *J. Phys. Colloid Chem.*, **54,** 437-444 (1950) Apr.

Series of investigations is designed to show the general characteristics of the dissolution of metals in hydrochloric acid from 25 degrees to —60 degrees C. From the data, order of reaction, rate of reaction at various stirring speeds and temperatures and temperature coefficient of reaction rate, i.e., activation energy are calculated.—BLR.

4.3, 6.3

Acid Corrosion Resistance of Tantalum, Columbium, Zirconium, and Titanium. Donald F. Taylor. *Ind. Eng. Chem.*, **42,** 639 (1950) Apr.

Above were tested in hydrochloric acid, sulfuric acid, nitric acid, phosphoric acid and ferric chloride solutions of various concentrations. Results show tantalum to be completely resistant to all solutions evaluated; columbium (Nb-niobium) had high resistance to all except hot concentrated hydrochloric acid and sulfuric acid; zirconium and titanium were the least resistant.—BLR.

4.3, 6.2

The Effect of Dilute Sulfuric Acid on Magnetized Iron. I. (In German) Georg Wagner. *Mitteilungen des Chemischen Forschungsinstitutes der Industrie Oesterreichs*, **4,** 29-31 (1950) May.

F. Ehrenhaft's "magnetolysis" in which magnetized iron dissolved in dilute sulfuric acid forms oxygen as well as hydrogen was studied. Results confirm Ehrenhaft's findings that the evolved hydrogen actually contains about 0.40 percent oxygen. The experimental arrangement is diagrammed and results are tabulated. 13 ref.—BLR.

PREVENTIVE MEASURES

• Non-Metallic Coatings and Paints

5.4, 3.8, 2.1

Fundamental Properties of Organic Finishes. Final Report. B. G. Brand and Others. U. S. Office of Naval Res., 1949, Contract No. N5-ori-III, Task Order IV, p. 1; *Prev. Det. Abs.*, **7,** Lac. 70 (1950).

An account of a study of physical and chemical properties of organic finishes. Coating/metal interface studies by reflection electron diffraction show that organic coatings are bonded to oxide films on the surface. Structural changes in organic films studied by transmission electron diffraction and electron microscopy showed that crystalline degradation is accelerated by exposure to U. V. light. Correlation between accelerated and natural weathering was found with respect to type of breakdown but not to time of failure.—RPI.

5.4, 6.6, 7.10, 2.3

Investigation of Engineer Board, Materials Branch, Fort Belvoir Plastic and Coated Metal Screening. PB38020, Frames 13, Board of Trade, Tech. Inf. & Docs. Unit, ORR, 162/49.

Tests on various paint coatings for protecting bronze, steel and galvanized iron screening are described and the results obtained compared with those of tests on nylon, Saran and glass cloth, coated with phenolic resin. Test methods used were accelerated weathering, salt spray, salt water immersion, distilled water im-

Corrosion Literature

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mersion, tropical chamber exposure and roof exposure.—RPI.

5.4

New Methods for Protecting Metals. H. Barron. *Ind. Fin.* (Brit.), **2**, No. 15, 146-9 (1949).

The use of strippable plastic coatings to protect metal against marring or corrosion during machining, storage and transit is discussed. Some details of the properties of a proprietary plastic solution, which is recommended for this purpose, are given.—RPI.

5.4, 6.3

Organic Coatings for Copper-base Alloys. A. Beyeler. *Pro-Metal*, **2**, No. 12, 521-8 (1949), *Bull. Brit. Non-Ferrous Metals R. A.*, **30**, No. 250-149 (1950).

The following matters are discussed: the difference between lacquering copper alloys and other metals; treatment before lacquering; various methods of applying and drying the lacquers; types of lacquers where drying is purely physical and where it is physico-chemical.—RPI.

5.4, 2.5, 2.6, 1.7

Report of Committee D-1 on Paint, Varnish, Lacquer, and Related Products. American Society for Testing Materials, Preprint 80, **1950** 61 pages.

Besides miscellaneous committee recommendations, this report includes tentative specifications for pure para red toner; method of test for hystane number kauri-butanol value and nitrocellulose diluting power of hydrocarbon solvents; methods for chemical analysis of blue pigment, chromium pigments, pigments containing iron and manganese and of zinc dust; and methods of testing varnishes, of preparing steel panels for testing the above and of testing drying oils.—BLR.

5.4, 1.7, 2.2, 4.2

Painting of Structural Steelwork, Joint Technical Panel J/Pl. Brit. Iron Steel Research Assoc. July 1949.

This second interim report gives details of the four series of exposure tests in progress at sites at Derby (industrial) and Brixham (marine). Five out of the 11 priming paints placed in the top grade after 2½ years exposure contained 40-60 percent zinc oxide in linseed stand oil/alkali-refined linseed oil media; 20-40 percent zinc chrome was also present in five top grade paints. The authors conclude that pigment mixtures based on zinc oxide have yielded priming paints giving a performance that is rather better than average. Of the eleven priming paints containing metallic pigments or lead soaps giving best results after 0.8 years, seven contained 50-75 percent zinc dust in various media and seven contained 25 percent zinc oxide. Exposure of the third and fourth test series on surface preparation and metallic coatings and on bituminous and tar paints was not commenced till 1948 and no results are yet available.—ZDA.

5.4

Plastics Temporary Protective Covering for Materials Subjected to Corrosion. H. Barron. *Chem. Trade J.*, **125**, No. 3261, 671-2 (1949).

Polyvinyl copolymers, ethyl cellulose and cellulose acetobutyrate are among the plastics suitable for temporary protective coatings. The ethyl cellulose compositions are applied by hot dipping. The vinyl copolymers are brought into solution and then applied by spraying or brushing. Both coatings can be readily peeled off.—RPI.

5.4, 6.6, 4.6

Protective Coatings to Prevent Aggressive Water Attack on Cement-Asbestos Pipe and Concrete. C. M. Bodach and J. F. Wilkes. Am. Chem. Soc. Meeting, Atlantic City, 1949; *Prev. Det. Abs.*, **7**, Plas 177 (1950).

Laboratory tests showed a black pigmented vinyl coating and a hot-applied wax melt coating to be most effective in preventing lixiviation of minerals from cement/asbestos pipe. The method of application is described.—RPI.

5.4

Rust-Preventive Effects of Red Lead, Graphite, and Iron Oxide Mixtures. (In German.) Kurt Basting. *Metalloberflache*, sec. A, **4**, 54-61 (1950) Apr.

Experiments were made to test the relative effectiveness of above mixtures dispersed in two different types of lacquer. Data are graphed and tabulated.—BLR.

5.4, 2.2, 4.2

Study of Primers for Ferrous Metals in an Atmospheric Exposure.—V. New England Paint & Varnish Production Club. *Am. Paint J. Conv. Daily*, **34**, No. 6C, 14-16, + (1949).

A report is given of the condition of the panels after 2 years exposure. Little deterioration has so far occurred. The only primers to show some failure were based on red iron oxide and calcium carbonate.—RPI.

5.4, 6.6

Plastics and Corrosion. H. Barron. *J. Roy. Inst. Chem.*, **74**, No. 1, 24-26 (1950) Feb.

For temporary (easily removable) protective coatings, polyvinyl copolymers, ethyl cellulose and cellulose acetobutyrate are suitable. Coatings can be applied from hot melt dipping compositions (ethyl cellulose) or from solution (polyvinyl chloride-acetate copolymers). Finally, for awkward shapes and any dimensions the coating may be sprayed on and built up (the cocoon process).—BNF.

• Miscellaneous Methods

5.10, 7.10

How to Protect Meters from Harmful Fluids. D. M. Considine and E. C. Murphy, Minneapolis Honeywell Regulator Co. *Paper Ind.*, **32**, No. 2, 161-165 (1950) May.

Causes of inaccurate instrument readings, as corrosion, precipitation and explosive fluids are discussed. Liquid seals, condensers, gas and liquid purge systems and settling chambers are used to prevent the passage of the gas or liquid into the instrument, but at the same time, transfer the measured pressure to the sensitive element within the instrument. Diagrams.—INCO.

MATERIALS OF CONSTRUCTION

• General

6.1, 8.8

Materials of Construction in the Chemical Industry. Soc. Chem. Ind. Preprint, 253 pp (1950). Published by the Society, 56 Victoria Street, London, S. W. I.

Papers presented at a conference at Birmingham University, April, 1950. The papers on aluminum, lead, tin, copper and noble metals will be found in the appropriate sections of this Bulletin. In addition there were five papers on ferrous metals; seven on concrete, cement, bricks, etc.; five on timber, asbestos, asphalt; six on plastics and rubber; and seven on refractories, glass, etc.—BNF.

• Non-Ferrous Metals and Alloys—Light

6.4, 5.4

Light Alloys as Structural Materials. G. Wood. *J. Roy. Inst. Brit, Archs.*, **57**, No. 6, 218-224 (1950) Apr.

In this review, the author stresses the importance of using zinc chromate primers to protect aluminum alloys against corrosion, where these are to be painted or are in contact with another metal.—ZDA.

6.4

The Structure and the Technical Production of Corrosion-Resistant Magnesium-Manganese Alloys. Uber den Aufbau und die technische Herstellung korrosionsfester Magnesium-Mangan-Legierungen. A. Schneider and H. Stobbe-Scholder. *Metall* (Germany) **4**, No. 9, 178-183 (1950) May.

The following characteristics almost completely describe the magnesium-manganese equilibrium diagram: With the solidification of magnesium-manganese alloys containing from 2 to 100 percent manganese primary crystals of pure manganese are formed. These are formed from magnesium-rich α-mixed crystals through peritectic transformation, with remainder melting about 3°C (5.4°F) above the magnesium melting point. The solubility of the manganese in molten magnesium amounts to about 2 percent at 653°C (1207°F), and rises sharply with increasing temperature to about 6 percent at 900°C (1652°F). In solid magnesium, manganese shows a marked temperature-dependent solubility with a maximum of about 3.5 percent at the peritectic temperature (E. Schmid and G. Siebel). On the other hand, the solubility of magnesium in solid manganese is very small and probably lies far under 1 percent. Technical precautions in the mode of operation were investigated by which undesirable amounts of iron were removed, effecting a considerable improvement in the corrosion-resistant properties of the magnesium-manganese alloys.—ALL.

• Metals General or Multiple

6.5, 6.7, 3.5

What's Ahead in Metals. *Prod. Eng.*, **87**, 102 (1950) Oct.

Noteworthy advances in the metals and metal-fabrication fields, the significance of which has not yet been fully evaluated by users, are described. These advances pertain to new methods of shaping steel, new types of metals for high-temperature and structural uses and novel metal-ceramic combinations, stainless and alloy steels, light metal alloys and production techniques. The latter techniques include "precision" casting methods, vacuum melting and

casting extremely large pressure forgings, and welding of new metal combinations. The search for new metal types has been concentrated on a group of high-melting-point "refractory" metals formerly used mainly as steel-alloying ingredients. This group includes zirconium, titanium, columbium, molybdenum, tantalum, tungsten and chromium, all possessing outstanding light-weight, strength and heat- and corrosion-resisting properties. In the field of alloys, molybdenum-, titanium-, chromium-, and cobalt-base, as well as iron-tantalum-columbium, "super-alloys" have been developed for use at very high temperatures and non-metallics (ceramics) were developed for operations beyond 2000° F. Other new developments are the semiconducting magnetic ferrites and new, light-weight, magnesium and aluminum alloys, as well as copper-base alloys, especially adapted for drawing and stamping operations. Data are also given on "rare" metals and powder metallurgy. German hydraulic 30,000-ton forging presses are described, as well as the large-scale drawing, forging, and extruding operations carried out by the USAF Manufacturing Methods Plant operated in conjunction with the Gerity-Michigan Corp. at Adrian, Mich.—TDD.

6.5, 1.3

Development and Present Position of Corrosion-Resisting Steel Castings. K. Roesch. *Stahl u. Eisen,* **70,** 596-607; dic. 606-607 (1950) July 6.

Development and present position (in Germany and other countries) of sorbitic, ferritic and austenitic steel castings. Data on corrosion-resistance and mechanical properties include a section on the nickel-molybdenum-base special alloys. 26 references given.—INCO.

6.5, 3.5

Metals for High Temperature Service. Ward F. Simmons and A. B. Westerman. *Metals Rev.,* **22,** No. 6, 5-9 (1949) June.—MI.

• Non-Metallic

6.6

Protective Rubber. *Iron and Steel,* **22,** No. 3, 3 (1949) Mar.—MI.

6.6, 3.5

Ceramics for High-Temperature Use. *Iron Age,* **164,** No. 24, 98 (1949) Dec. 15.—MI.

6.6, 3.5

Ceramists Make Progress on High Temperature Refractories. *Iron Age,* 165, No. 21, 80-81 (1950) May 25.—MI.

6.6

Hard Rubber as an Engineering Material. J. R. MacKay. *Mat. and Meth.,* 31, No. 2, 54-56 (1950) Feb.—MI.

6.6

Thermal Ageing Properties of Cellulose Insulation Materials. G. Malmlow. *Kgl. Tek. Hogskol. Handl.,* **19,** 1-67 (1948). *Prev. Det. Abs.,* **7,** E 52-54.

Pyrolysis is considered the primary cause of decomposition in the thermal ageing of cellulose insulation materials. Impregnation with oils or varnishes did not affect the decomposition rate, even in the presence of copper or organic acids.—RPI.

6.6, 7.2

Plastic Pipes Invade New Markets. *Modern Plastics,* **27,** No. 7, 68-75 (1950) Mar.

Chemical resistance, light weight and ease of installation are among the reasons why plastics are replacing conventional material in many industrial piping applications. Saran is inert to a wide range of chemicals and can eliminate replacements of the metal (usually stainless steel) pipe previously used, chemical contamination of the fluid and leaking due to corroded piping. Polyethylene is used in food industries, soft drink plants and in pharmaceutical plants. Butyrate pipe, called Tenite II was used to draw off salt water from crude oil deposits in place of the cement-lined steel pipe usually used. Corrosion-erosion resistant pipe and fittings for shipboard use are made of glass cloth and polyester resin and is called Glasweld. Its tensile strength is equal to that of stainless steel pipe, but its specific gravity of 1.8 gives a strength-weight ratio of 27,800 as compared with only 6400 for stainless steel. It is recommended for carrying mild acids such as dilute hydrochloric acid and dilute sulfuric acid. Applications of the plastic pipes are tabulated.—INCO.

6.6, 5.4

Paints for Cement. H. Rabaté. *Trav. Peint.,* **4,** No. 4, 162-163 (1949).

Thorough removal of all loose material, dirt, effluorescence and the products of any chemical attack on the cement, mortar or concrete by wire brushing is necessary before painting. Chemical cleaning by acids is not recommended because of the large volumes of water needed for washing down which soak into the stone and take a long time to dry out. The need to allow sufficient time for new cement to dry out is also stressed. Suitable paints for cement are those based on lime, Portland cement, silicates, ethyl silicate, emulsions containing 5-15 percent oil, tar, spirit-soluble, or emulsified asphalts, rubber or chlorinated rubber, varnishes containing indene or coumarone resins, and emulsions based on vinyl or styrene copolymers. Paints based on oils should only be used on thoroughly dried out masonry or on that which has been neutralized by treatment with zinc sulphate solution or magnesium or zinc fluorosilicates.—RPI.

6.6, 8.3, 5.6

Microcrystalline Wax Coating of Concrete Tanks. C. B. Schreffler, Roma Wine Co. *Wines and Vines,* **31,** No. 6, 29 (1950) June.

The most rapid deterioration of the concrete used in winery construction occurs where the surface is exposed to fermenting or moving liquid, especially when it contains solids or dissolved gases. Tests have shown that concrete coatings break down rapidly due to penetration of carbon dioxide when exposed to fermenting liquids or in some cases it was difficult or impossible to bond the coating to the concrete strongly enough to prevent it from peeling off. One material that has proved satisfactory when properly bonded is microcrystalline wax. This has an almost amorphous structure and does not crystallize even after repeated melting and solidifying. It remains flexible at low temperatures and does not chip due to expansion and contraction of the surface. The flexibility and adhesiveness make it resistant to mechanical erosion. The wax film is highly impervious to water and dissolved gases and is not seriously blistered by exposure to carbon dioxide or moisture. Good bonding and penetration is obtained by using a patented gun which sprays the melted wax, electrically heated almost to the flash point, surrounded by a stream of hot air also electrically heated to a higher temperature than the wax. The hot air drives out the moisture from the pores of the concrete and as it cools a vacuum is formed that draws in the melted wax.—INCO.

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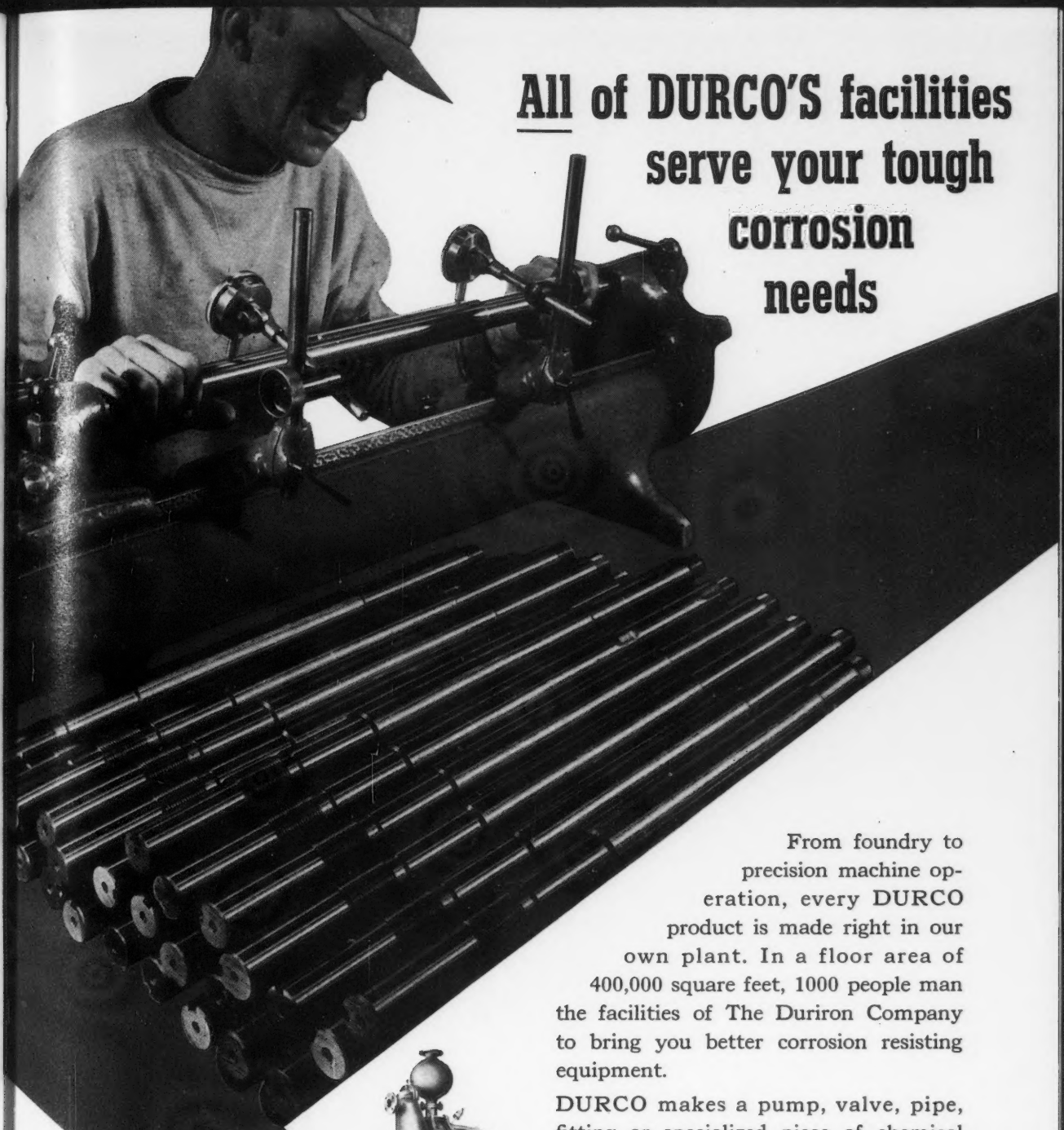

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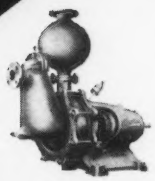

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